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Stormwater Management in the New Jersey Coastal Zone

Dover Township, NJ

April 1989

A report prepared by Cahill Associates for the
State of New Jersey, Department of Environmental Protection
Division of Coastal Resources, CN 401, Trenton, New Jersey 08625

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By
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EXECUTIVE SUMMARY

STORMWATER MANAGEMENT MANUAL

for the

NEW JERSEY COASTAL ZONE

Executive Summary

The purpose at the outset of this Manual preparation was to review New Jersey's coastal permitting program, as administered by the Department of Environmental Protection-Division of Coastal Resources, and determine if there were innovative practices and techniques which NJDEP could incorporate into its regulatory program in order to improve coastal water quality. However focused the initial question might appear, the issue really assumes a reasonably thorough understanding of what NJDEP regulates in its coastal permitting program, where it regulates, and how it regulates--issues which turn out to be remarkably complicated. Also assumed is the fact that both the causes of water pollution and the exact extent of degradation in coastal waters is known. In the course of preparing this Manual, it has become apparent that these questions are anything but straightforward. In fact, the correct answers to such basic questions require water quality sampling data and other information which simply is not available at present.

In order to reach our desired goal--improved coastal water quality--it has been necessary to diverge from a neat listing of improved best management practices or techniques for pollutant reduction which could be incorporated into the coastal permitting process. This document discusses broader issues which encompass more far-reaching water quality considerations, such as the State's total permitting jurisdiction. Chapter Five develops not only an array of best management practices, but also is preceded in Chapter Four by a system for selecting different water quality techniques based on what is being proposed and where it is proposed. Other important "non-structural" water quality recommendations are made which must be implemented if significant increases in pollutant loading to the coastal waters are to be prevented. These measures may have to be "retrofitted" to existing development if the overall problem is ever to be confronted. The system is both radical and controversial. It is far from refined. Nevertheless, with some additional scrutiny and adjustment, adoption of these recommendations should offer considerable water quality benefit, even while coexisting (peacefully and otherwise) with the proposed land development projected to continue in New Jersey's coastal drainage.

Chapter One presents the physiographic setting of the coastal zone and defines its extent--areas with direct Atlantic coastal drainage. The unique nature of its overall hydrology is considered, as well as the subtle and complex ecology which evolves from inland headwaters downstream to estuarine back bays and into the ocean waters. Water quality trends are reviewed as these trends are known, and an attempt is made to understand what is happening to the aquatic system, as well as major sources of pollution. This chapter covers a tremendous amount of material very quickly, but is essential if the reader is to begin to understand the nature of the system as well as the scientific basis for change and improvement. Even with the surprising lack of water quality data which confronts us, water quality in the coastal region is an ever-expanding topic that is not easily summarized. In an effort to keep the Manual of reasonable length, massive amounts of information and computer data were deleted, with only data summaries remaining. Even so, this report often exceeds the bounds of the initially conceived document.

Chapter Two discusses both growth--what the State will regulate in the future--and regulation--how this growth will be affected. Although this report is hardly the first to acknowledge the "holes" in the State's regulatory program, we are compelled to clarify what the current coastal regulatory program can and cannot do. The chapter points out the large inland geographical areas which are in fact hydrologically linked to coastal waters from a nonpoint water quality perspective, but which have been excluded from the State's coastal regulatory program. A second major flaw discussed is the extensive development which is excluded from permitting requirements, regardless of proximity to the coast. It is concluded that in the past, the regulatory program has not had any direct effect on the bulk of the land development projects in the relevant water quality zone of impact (i.e., direct Atlantic coastal drainage). Because of these holes in the regulatory system, a large percentage of the substantial growth which is projected for the future will continue to be unaffected by the present coastal permitting program, regardless of <u>how</u> that program is conducted by NJDEP, and regardless of what best management practices are developed here and required. The conclusion is rather negative, but nevertheless, we would feel remiss in our responsibilities to the State if this critical reality were not pointed out. Solving this problem, of course, transcends making lists of best management practices and will require both enabling legislation and modification of regulations operationalizing the coastal permitting program. For comparison, the growth projections for the Atlantic coastal drainage (the area tributary to the Atlantic Ocean, excluding both Delaware and Hudson-Raritan drainage), is considered. Again, much of this work goes beyond the initial concept for this Manual, but is necessary if the Manual is to have meaning.

Considerable time has been devoted to understanding how the coastal permitting program actually works, within its varying levels of conditions and constraints. Detailed discussions were held with Division of Coastal Resources permit staff, and permits issued in the past were reviewed in order to appreciate requirements already imposed. What has emerged is the impression of a tremendously understaffed and overworked group of reviewers, trying sometimes desperately to impose restrictions in the face of frequent challenges and pressures of all types. In frustration, some of us may be tempted sometimes to be overly critical of the State's regulatory efforts and to scapegoat an admittedly imperfect system. Nevertheless, we are struck by the level of commitment and capability which we have found in the Division.

Chapter Three provides background information relating to the causal connections between land development and nonpoint source water pollution--out of necessity. Pollutants that make their way into coastal waters will vary by the type and amount of land development which occurs. If effective management practices are to be developed and imposed, we must understand how land pollutants are generated. We must also understand how pollutants are transported, in what forms, and how they accumulate in different phases of the ecosystem--if cost-effective interventions are to be successfully engineered. This discussion concludes with a listing of the pollutants most critical in coastal waters and which must be managed in New Jersey's coastal drainage. An ambitious attempt at establishing water quality loading standards for these pollutants is made, beginning a process that will surely be the subject of future debate and controversy.

Chapter Four establishes a best management practice decision matrix--a set of directions for applying various best management practices. The directions are generalized and, like any such system, will have to be further detailed as experience is gained. The matrix and method emphasize several major factors:

- o whether the development site discharges to tidally-dominated waters o the renovating capacity of the soil mantle (i.e., whether the soil cover is of sufficient thickness and with adequate cation exchange capability to filter dissolved and particulate pollutants from the stormwater drainage)

o nature of the pollutant source (both in terms of rooftop, paved area, or pervious portion of a particular site as well as in terms of the land use being proposed)

o proximity to sensitive groundwater uses such as municipal wells

This Manual establishes the framework for a system which moves the State ahead, combining scientific information with a full appreciation for NJDEP's legal and institutional responsibilities. It tries to respect the State's need to be institutionally conservative, and yet at the same time take action, some degree of risk notwithstanding, so that water quality improvements can be made. It is understood that the proposed system is controversial and that many will take issue with some of the specific values and coefficients which have been assigned. For example, the consideration of seasonal high water table (SHWT) as a selection criterion for certain BMP's can be interpreted rigidly, eliminating a number of possible solutions, or it can serve as a guide in chosing the best available alternative, as is recommended in Chapter Four. Some of these values and many of the steps in the process may have to be modified, as various issues are further refined and more information is brought to bear. Nevertheless, the application of such a system as soon as possible would constitute a giant step forward in the State's processing of coastal permits. In a dynamic environment, the State can no longer afford to wait on perfect scientific knowledge.

The Manual concludes with Chapter 5, a listing and description of the various best management practices themselves which are driven by the system developed in Chapter 4. These practices are diverse and can be used with some degree of flexibility from site to site. Probably the most passionately held belief is the importance of implementing what is called a "minimum disturbance/minimum maintenance" type of approach to new land development within the coastal drainage. The approach not only offers the potential of reducing construction phase nonpoint source pollutant generation, but, more importantly, limits the amount of ongoing pollution created by standard site maintenance practices. Furthermore, the application of a minimum maintenance/minimum disturbance offers substantial user benefits, reduces costs, provides any number of additional environmental benefits, and generally makes a tremendous amount of sense for new land development in coastal communities.

From the extreme environmental perspective, no new land development probably would ever be permitted. However, if the realities of our system are to permit land development to occur at the considerable densities currently allowed, then we should insist at minimum that this development adhere to very specific performance standards. Once practices such as minimum disturbance/minimum maintenance gain acceptance and builders come to appreciate the inherent logic behind such techniques, this best management practice may be transferable to areas of existing development. Appendix B offers case studies which serve as models for coastal development in conformance with this policy and which can be adapted to many New Jersey contexts.

Nonpoint source pollution is certainly not the only water quality problem facing New Jersey coastal waters. Any number of unfortunate occurrences in recent years have made us aware that pollution of coastal waters stems from an array of sources, from illicit dumping of hospital wastes and ill-conceived ocean dumping of sewage sludge to the continuing discharge of rapidly increasing amounts of nutrient-rich sewage effluent from an array of municipal treatment plants along the coast. Nevertheless, the nonpoint source component of the problem is both real, urgent, and increasing in importance. The objective of this Manual is to demonstrate that immediate action can and should be taken to reduce nonpoint source pollutants and improve water quality in the coastal region.

INTRODUCTION

STORMWATER MANAGEMENT MANUAL

for the

NEW JERSEY COASTAL ZONE

Introduction

"Every time it rains, massive amounts of pollutants are washed into streams, rivers, bays, and directly into the ocean."

("New Jersey's Coastal Ocean," NJDEP, 1988)

The quality of water in the coastal zone of New Jersey is degraded by a variety of pollution sources. Problems are apparent in both the estuarine environment of the bays and inlets which lie behind the barrier islands, and in the ocean waters which wash the shoreline. The nature of these problems and their causes is varied, but there exists an accurate public perception that a previously unspoiled environment and critical natural resource has become degraded. Although scientists, citizens, and elected officials debate the degree and extent of damage caused by an assortment of man's activities along the coastal zone, there is little question that the past ten years have witnessed both subtle and dramatic pollution incidents which have focused the public spotlight on this ecosystem. As we evaluate and study the causes and effects of this degradation, it is appropriate to review and revise those regulatory programs which were created to protect this fragile environment. This Manual is one such effort to improve the methods and practices of stormwater management under the set of regulations established for the coastal zone, and implemented by New Jersey's Dept. of Environmental Protection-Division of Coastal Resources (DCR). We also have attempted to design a program which is compatible with New Jersey's emerging stormwater management program, being implemented by NJDEP's Division of Water Resources.

The sources of coastal pollution are several fold: sewage sludge and other waste materials discharged or dumped into deep ocean waters which are then carried to the shore, residual wastewater (sewage treatment plant effluent) which is inadequately or partially treated and discharged directly to the near shore environment or indirectly to tributary rivers and streams, various pollutants released from marinas and from both pleasure and commercial boating activity, fallout of air pollutants, and stormwater pollutants which are flushed from the land surface with each rainfall, accumulating in the tributary streams, bays, harbors, and the near shore waters. In fact, even the rainfall itself has its share of pollutants. Although a comprehensive and meaningful data record of water quality is lacking--there simply has not been adequate water quality sampling and monitoring to adequately assess the nature and extent of water quality problems and their causes in coastal waters, some ambitious studies have attempted to make causal linkages. Such studies have estimated the relative share of pollutant loadings associated with each of these several basic sources. At best, this work is only preliminary in nature. Most probably, the proportional responsibility for pollution varies in different portions of the coastal environment. Consequently, all potentially responsible sources and causes of pollution must be addressed to understand the complete picture of coastal water pollution. This Manual is concerned with only one of these pollution sources--the impact of stormwater on the coastal marine environment, and how best to manage our activities on land through improved stormwater management practices to restore and maintain the quality of these coastal waters. As is being recognized increasingly, this nonpoint source stormwater related component of pollution is one of growing importance.

> "Most people think of ocean dumping of wastes from barges or scows as the primary cause of pollution. Although it is a very visible source, the overall contribution is minor in comparison with land based pollution flowing out into the ocean from our rivers, bays, and coastal areas. Rivers pick up pollutants from many sources and deliver them to the coastal ocean in a steady flow....,
>
> "Storm water discharges, runoff from agricultural lands, and urban runoff are generally not regulated by permit and thus become a major source of pollution into rivers and streams."
>
> ("New Jersey's Coastal Ocean," NJDEP, 1988)

Throughout this report, it must be kept in mind that although stormwater-related pollutant loadings to coastal waters appear to be of major significance and of increasing importance as coastal development proliferates, other sources of pollution do exist. The overall degradation of water quality cannot be attributed to stormwater alone in most areas, and it may not be the most severe cause of water pollution in some areas of the New Jersey coastal zone. The pollutants which contaminate shellfish, increase bacterial levels, and produce excessive growth of algae along the shoreline vary with respect to source in different areas of the coast, from the industrial and commercial harbors of the north to the marina-lined bays of the south. But the overwhelming evidence indicates that the pollution load washed into these waters with each storm is a significant part of the problem, and must be corrected if New Jersey is to protect its single greatest natural resource and restore public confidence in water quality in the coastal zone.

The initial purpose of this Manual was to delineate an array of best management practices or BMP's which could be incorporated into the Division of Coastal Resource's permit review, in order to reduce future nonpoint source pollutant loadings. However, as information has been gathered and the nature of the coastal permit program evaluated, this scope has been expanded to include broader regulatory issues. In the following sections, considerable effort has been given to developing an understanding of existing water quality, water quality problems, and trends in coastal water chemistry. Thought has also been given to the regulatory questions of the jurisdictional effectiveness of the coastal permitting program, both in terms of its geographic coverage and the types of development proposals requiring a permit. These are critical issues, possibly far more important to the overall effectiveness of the program in controlling pollutant loadings into coastal waters, than recommendations of improved practices in those developments which do manage to get included within the program. At the same time, analysis has been directed toward reviewing typical permitting situations throughout existing coastal jurisdiction, reviewing requirements imposed as part of the permit process, and devising improved management concepts and practices which can be immediately imposed in the Division's permit evaluation process.

In this context, one might question why only new development should be a concern, given the fact that the degradation presently experienced in coastal waters is the result of past mistakes and existing conditions. Theoretically, consideration should be given to retrofitting existing development sites, modifying existing stormwater elements with many of the water quality measures discussed herein, and possibly adopting additional stormwater management measures. Such a program, however, goes well beyond the present responsibilities of the Division of Coastal Resources and NJDEP's existing mandate. Furthermore, significant administrative, socioeconomic/fiscal, and other types of questions need to be addressed before action is taken on the problem of existing sources. Nonetheless, these existing source problems are real and have to be dealt with if water quality problems in coastal waters are to be remedied. The Federal stormwater management program which is now being phased in by EPA anticipates just such an effort, although it will be many years before that program has any direct effect on the New Jersey coastal region.

CHAPTER 1.

THE COASTAL ZONE OF NEW JERSEY

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THE COASTAL ZONE OF NEW JERSEY

Physiographic Setting

In order to understand the process of pollution in the coastal zone, it is first necessary to consider the physiographic region which forms this marine coastal environment. Because the focus of our concern is with the mechanisms of pollutant transport during stormwater runoff, the physical conditions which produce this runoff are critical determinants in the natural process which has been altered by anthropogenic or manmade activities.

The unconsolidated sedimentary deposits of sand, marl, and clay which comprise the southern half of New Jersey were laid down in thick beds over the past 135 million years. These beds dip southeast toward the coast and extend beneath the Atlantic Ocean to the edge of the Continental Shelf (NJDEP, 1984). Coastal plain sediments increase in thickness from a feather edge in the northwest to a depth of 4,500 feet near Atlantic City and become still thicker beneath the ocean. Over the millennia, the shoreline has varied greatly as sea levels have fluctuated. The coastline we see today is only the most recent boundary between land and sea, with the evidence of both earlier floodplains and marine environments obvious along the coast. Many of the estuaries along the shore were the lower reaches of former river valleys inundated during the past 12,000 years, with barrier islands formed by erosion and deposition to the east of the mainland. Between the mainland and the barrier islands, there exist embayments and estuaries of different sizes and configurations. Inland erosion and marine sediments have gradually filled in this area, creating extensive wetlands and yet another phase of the coastal ecosystem (Odum et al, 1974; Clark, 1977). This unique combination of habitats is illustrated by the satellite image shown in Figure 1, distinguishing between the edge of coastal land mass, the barrier islands and the estuarine embayments which lie between.

The general landform of the coastal region is flat. Approaching the New Jersey coastline from the Piedmont uplands to the west or north makes one aware of the transition into this distinct physiographic region, extensively covered by pitch pine and cedar forest of moderate proportions. It is this vegetative land cover, of course, which creates another unique aspect of the coastal zone--the Pine Barrens. Much has been written concerning the Pine Barrens of New Jersey (McCormick and Jones, 1973), but their co-occurrence with the Atlantic coastal drainage area (Figure 2) is not accidental. The land mass here, the vegetative cover, the surface and sub-surface drainage all are highly interrelated factors in the coastal environment 's pre-disturbance state.

At the outset of this report, it is critical that the geographic concept of the coastal zone be established. Definition of terms is critical, especially in this case, where so much of the literature refers to various areas--the coastal zone, the coast, the shore and shoreline -- without specifying and/or mapping exactly the area under discussion. Frequently, "coastal zone" is used interchangeably with the "CAFRA zone", the latter being a complex designation based on a blend of both physical and environmental features, as well as numerous other regulatory, administrative, and political boundaries.

Figure 1. Satellite Image - New Jersey Coastal Region (USGS, 1972)

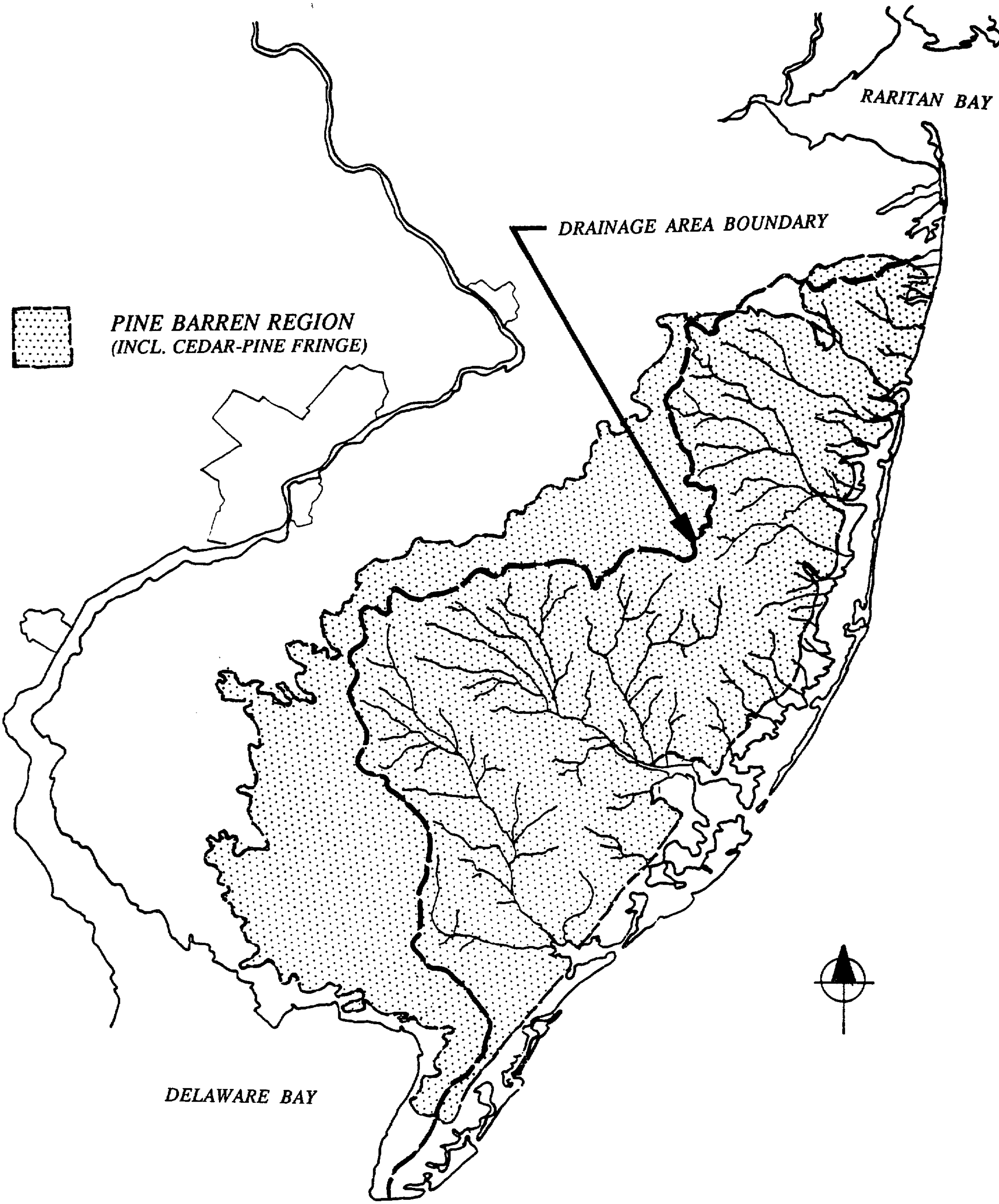


Figure 2. Pine Barrens with Coastal Drainage Boundary (Cahill and Associates, 1988)

For this report, which focuses on stormwater-related water quality pollution, the obvious criterion in determining the study zone is drainage. Therefore, the Atlantic coastal drainage basins are frequently referred to in this Manual and used as a basis for analysis. Technically speaking, of course, all of New Jersey drains to the Atlantic Ocean. However, those portions to the west and north which are either Delaware River or Delaware Bay drainage have been excluded from most of the discussion here. Hydrologically, this drainage is not related in the same way to coastal water quality as what we call the Atlantic coastal drainage (interrelationships exist, but are less direct). In any case, a large portion--though not all--of this Delaware Bay drainage is contained within the coastal permitting jurisdiction and will be enhanced as the result of improved best management practices being required under the coastal permitting process. Best management practices identified in this Manual will benefit water quality in this zone as well and should be applied. Due to the constraints of this study, however, we have not analyzed water quality conditions in this Delaware drainage in detail. This analysis should be undertaken in the future by NJDEP.

Similarly, we exclude that area in the north which drains into the Hudson-Raritan Bay complex, a water mixing zone of added complexity which receives inputs from diverse inland sources in both New Jersey and New York, as well as numerous point source and nonpoint source contaminants from the Bay complex itself. Most of this area within northeastern New Jersey is beyond the jurisdiction of the coastal permitting program as it currently is defined, and the major portion of the drainage area is literally outside of the State itself. Again, to the very limited extent that coastal permitting has influence over new development in this region (basically through Waterfront Development Permits), water quality will benefit if improved best management practices are imposed. However, the tremendous complexities of both the Delaware and Hudson-Raritan Bay drainage systems--their hydrology, vast numbers of pollutant sources, resource values different in nature and extent than for the Atlantic coastal drainage, and limitations in permit jurisdiction--all point to additional priorities and approaches, in terms of coastal water quality management. In fact, a few of the measures discussed later in this Manual, such as those which deal with combined sewer outfalls (CSO's), are only applicable to these older urban coastal areas from Raritan Bay northward and are not relevant to the Atlantic coastal drainage area.

> **Typically, the area of primary interest in this Manual will be the Atlantic coastal drainage (Figure 3 and Table 1), a land area of approximately 1,750 square miles (or 2,000 square miles including bay areas and barrier islands), extending inland as much as 40 miles from the New Jersey coastline. This Manual is designed to offer specific guidance for new development along the 127-mile coastal region from Sandy Hook to Cape May, with potential application elsewhere within existing NJDEP permitting jurisdiction.**

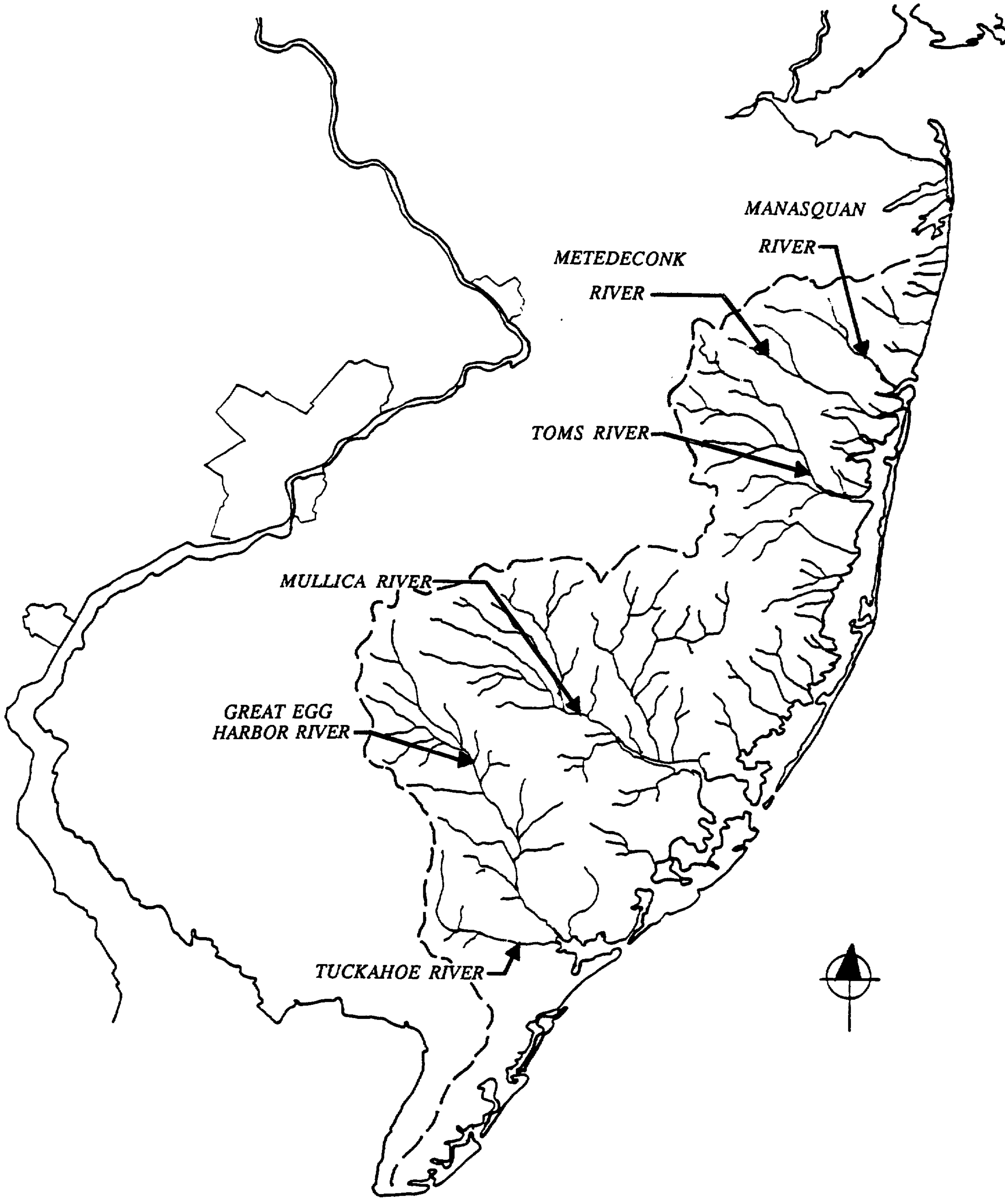
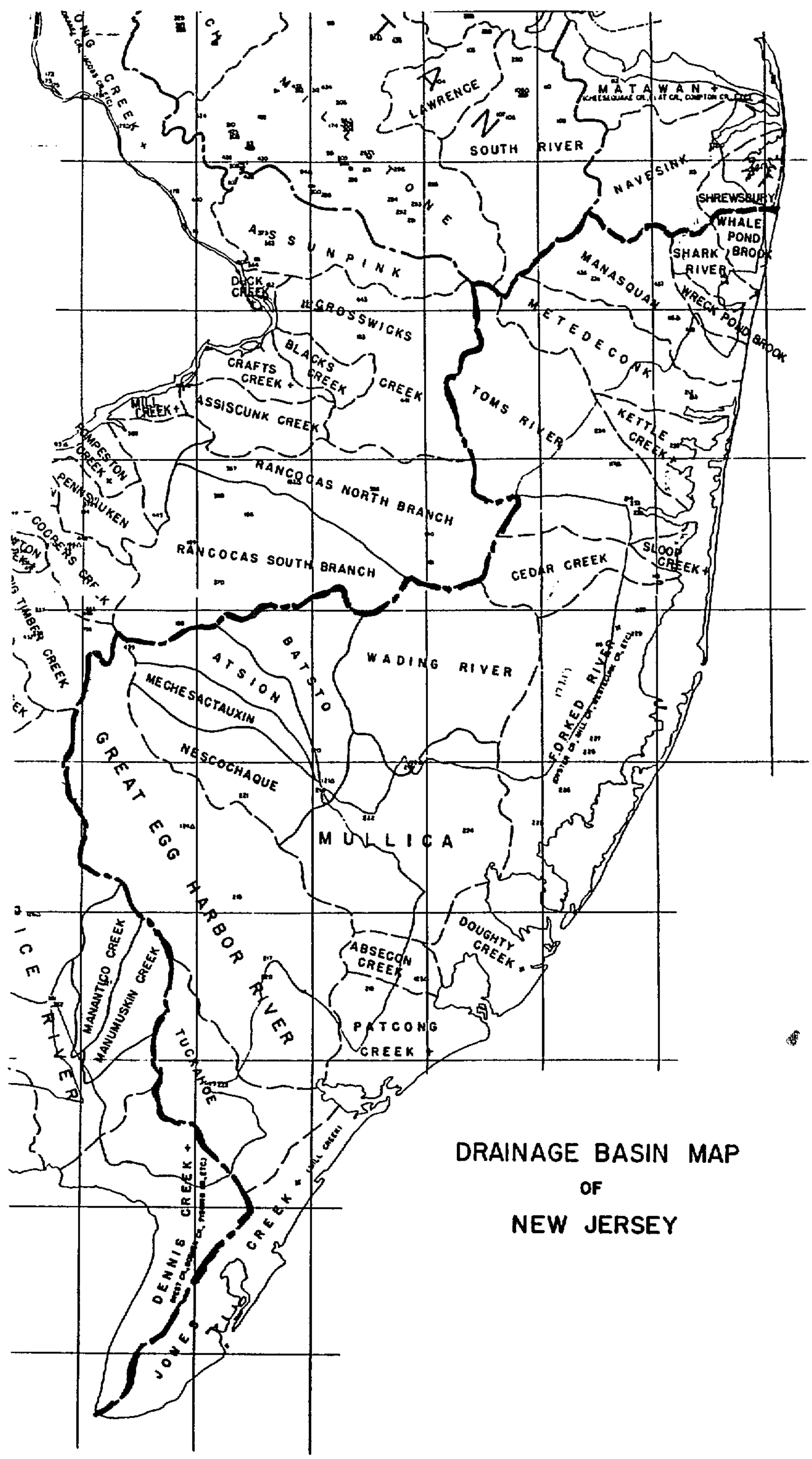


Figure 3. Atlantic Coastal Drainage Area (Cahill and Associates, 1988)

Table 1. Atlantic Coastal Drainage Basins (NJDEP, 1972)

	AREA (sq.mi.) USGS	DEP
TO ATLANTIC OCEAN		
Whale Pond Br.	6.82	17.30
Poplar Br.	3.86	
Deal Lake*	6.66	
Shark R.	23.00	23.00
Polly Pod Br.	1.49	
Wreck Pond Br.	12.70	14.20
Manasquan R.	81.80	80.50
TOTAL	136.33	135.00
TO BARNEGAT BAY		
Metedeconk R.	89.10	73.90
Kettle Cr.	15.30	18.00
Goose Cr.	2.69	
Toms R.	192.00	191.20
Sloop Cr.	2.49	6.10
Potter Cr.	2.33	
Clamming Cr.	1.30	
Cedar Cr.	55.30	55.80
Stouts Cr.	2.50	
Wrangle Cr.	0.67	
Forked R.	25.80	142.30
Oyster Cr.	12.90	
Fresh Cr.	0.50	
Waretown Cr.	3.15	
Lochiel Cr.	2.17	
Double Cr.	3.17	
Gunning R.	6.36	
TOTAL	417.73	487.30
TO MANAHAWKIN BAY		
Cedar Cr.	3.81	
Manahawkin Cr.	2.36	
TOTAL	6.17	
TO LITTLE EGG HARBOR		
Mill Cr.	22.90	
Cedar Run	8.39	
Dinners Pt. Cr.	4.41	
Westecunk Cr.	25.00	
Parker Run	1.66	
Jesses Cr.	1.63	
Sapp Cr.	0.74	
Tuckerton Cr.	15.90	
TOTAL	80.63	
TO GREAT BAY		
Batso River	71.10	66.90
Wading River	188.00	145.60
Atsion River		42.80
Mechesactauxin		46.00
Nescoochaque	43.80	76.70
Lower Mullica		191.60
Mott Cr.	4.82	
*Mullica R.	569.00	
TOTAL	573.82	569.60
TO REEDS BAY		
Doughty Cr.	5.06	9.00
Cordery Cr.	1.42	
TOTAL	6.48	9.00
TO ABSECON BAY		
Absecon Cr.	26.40	26.40
TO GREAT EGG HARBOR		
Patacong Cr.	29.10	29.10
Great Egg Harbor R.	347.00	337.70
*Tuckahoe R.	102.00	102.00
Miller Cr.	0.34	
*Crook Horn Cr.		
Ben Elders Cr.	0.44	
TOTAL	478.88	468.80
SOUTH OF GREAT EGG HARB.		
Jones Cr.	23.71	28.80
TOTAL COASTAL DRAINAGE	1750.15	1724.90



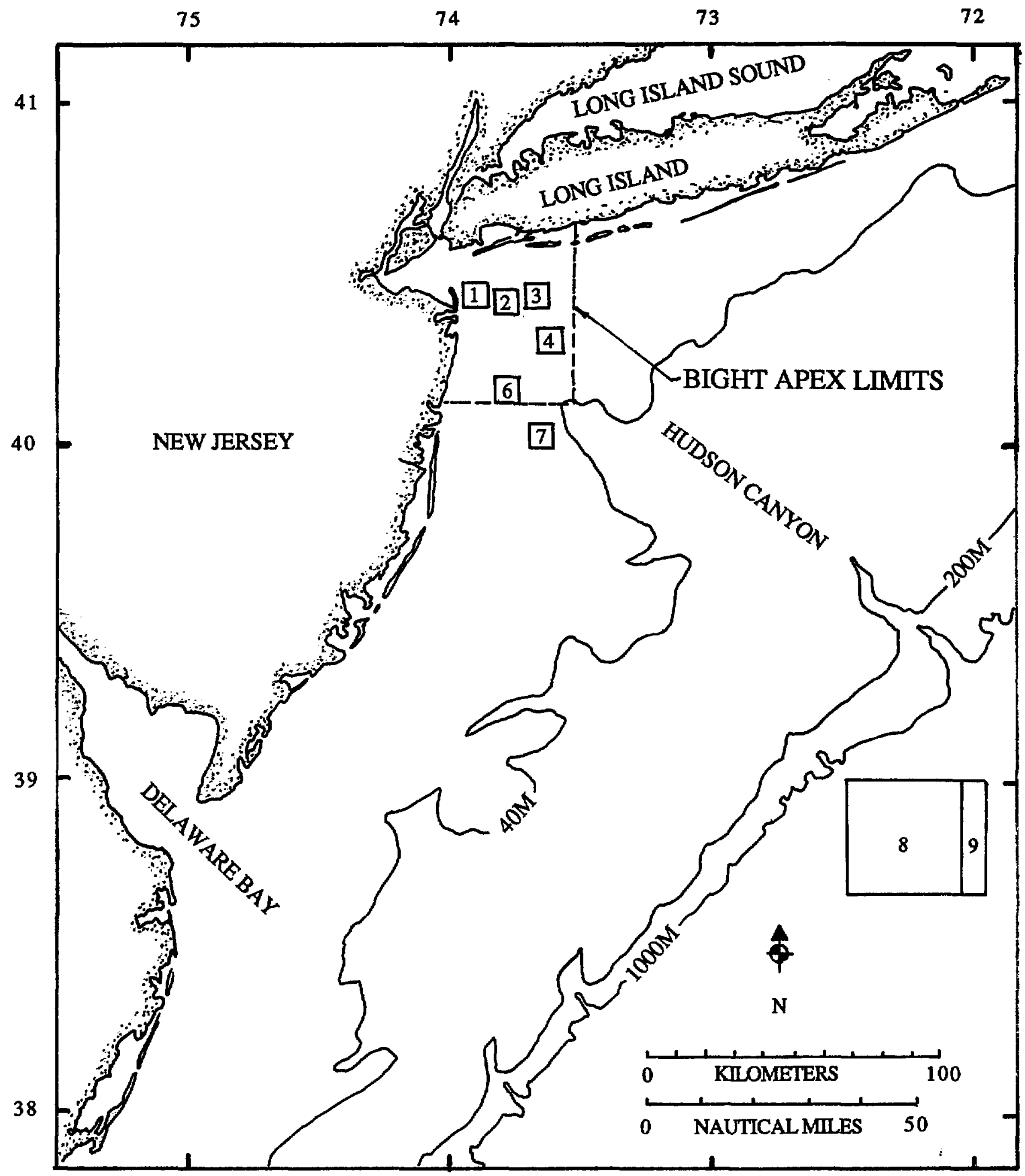
DRAINAGE BASIN MAP OF NEW JERSEY

Hydrology and Hydrologic Variability

The hydrology of the Atlantic coastal drainage is complex and not readily apparent. Although the entire 1,750 square miles of land area as shown in Figure 3 drains to the coast, one might assume that the quality of water along the New Jersey shore was largely a function of conditions in the ocean itself. One might also assume that if land activity had any effect on the ocean, most of that influence would be quite localized and related primarily to the land activity immediately adjacent to the coast. One might assume that conditions inland more than a mile or two would have little bearing on ocean water quality. True, the greater the proximity of man's activity to the water's edge, the greater the likelihood that pollutants will enter the water directly. But there is also a serious conceptual error committed if the functioning of the total hydrologic system--the total drainage area--is not considered in the analysis of stormwater pollution in coastal waters. The 764 billion gallons of fresh water draining to the estuaries and ocean each year from this defined land mass (Atlantic coastal drainage area) is a major, if not the primary, water quality determinant. The importance of taking into account this total stormwater drainage component is growing ever more compelling, as land development proliferates inland from the barrier islands and bayshore areas and occupies vastly more coastal acreage with commensurate increases in nonpoint source pollutants.

Understanding the movement of waters in the coastal zone is extraordinarily complex. Waters drain from inland basins, flowing directly into streams and rivers or moving through the subsurface to emerge as baseflow in streams and back bays. Tidal effects occur within the lower reaches of the drainage system and back bays, mixing ocean water with mainland drainage. This mixture of brackish water is gradually displaced from the embayments with each tidal cycle into the near shore ocean water. Several smaller stream and river systems discharge directly along the coast. In the north, the major coastal water influence is the drainage from the Hudson-Raritan Bay, whose considerable drainage flows out of New York Harbor tend to follow the Jersey coast, flowing southward as far as the Barnegat Inlet. Although a significant amount of research has been conducted analyzing the way coastal waters mix in what is known as the "New York Bight" (Figure 4), the precise hydromechanics are extraordinarily complex and are not known with certainty. Also, because there has been considerable ocean dumping of sewage sludge historically in nearshore areas (9 miles out from Sandy Hook) and now in zones more distant (106 miles out from Atlantic City) and because there has been considerable ocean disposal of dredged material and other contaminants in the Bight Apex, the overall currents within the Bight affect near shore coastal water quality and are important to understand. To the south, the flow from Delaware Bay tends to travel northward, although its pollutional impact on the New Jersey's Atlantic coastal waters seems to be far less. Clearly, the impact of stormwater pollution from Atlantic coastal drainage must be understood within this complicated coastal water context.

There are other hydrologic characteristics peculiar to this coastal region which have important ramifications for the generation of nonpoint source water pollution and coastal water quality. Within a typical stream system, one can characterize the process of storm runoff from rainfall by considering the increase in stream flow at some point downstream in the drainage basin. Following rainfall, the stream level and corresponding flow rises dramatically. This movement of flood flow produces the phenomenon which scientists have called a "hydrograph" (Figure 5), a depiction of flow versus time. These diagrams of flow versus time have been extensively analyzed over many years. When combined with explanations and mathematical equations developed to sort out the various pathways of



1. DREDGED MATERIAL
2. CELLAR DIRT
3. SEWAGE SLUDGE (12 MILE SITE)
4. ACID WASTES
6. WRECKS
7. WOOD INCINERATION
8. INDUSTRIAL WASTES (106 MILE SITE)
9. MUNICIPAL SLUDGE (106 MILE SITE)

Figure 4. The New York Bight (NJDEP, 1988a)

Upland and Coastal Hydrographs

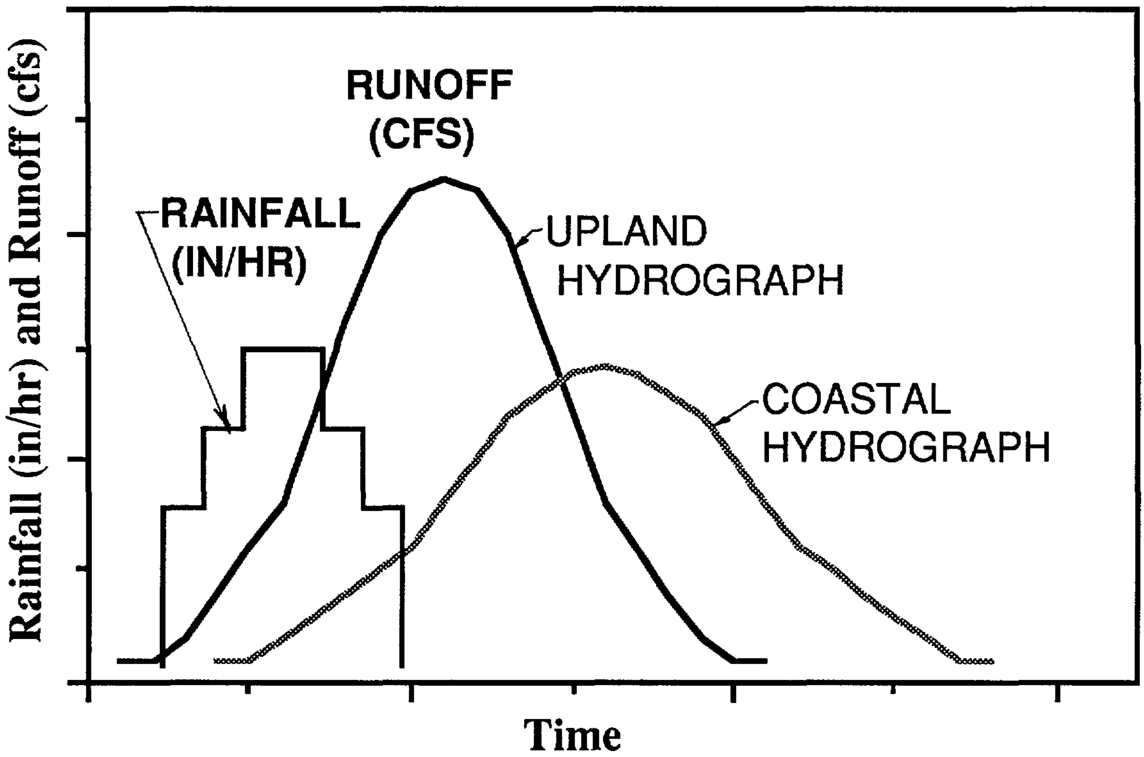


Figure 5. A Comparison of Typical Upland and Coastal Hydrographs (Cahill Associates, 1988)

rainfall movement from land surface to stream, hydrographs form the basis for the analysis of stormwater runoff as a part of the hydrologic cycle.

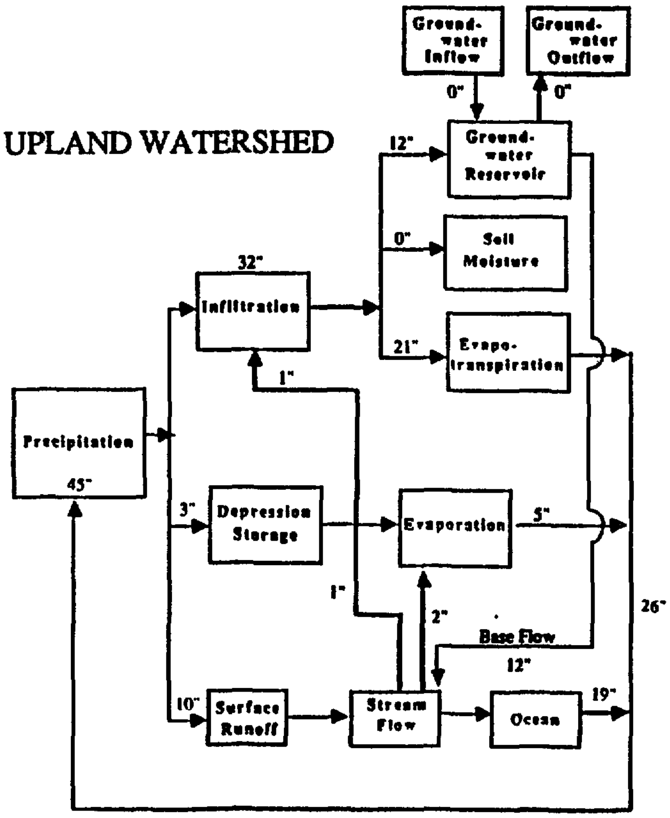
In the New Jersey Atlantic coastal drainage region, the hydrologic cycle is very different from an inland watershed. This difference can best be illustrated by Figure 6, which contrasts upland and coastal drainage systems in terms of the manner in which rainfall moves through the respective land surface and subsurface drainage networks. The two systems are similar, in that as the diagram shows, the incident rainfall does three things - a portion of the rainfall is immediately returned to the atmosphere as evaporation; a portion soaks into the ground and travels very slowly toward the surface stream through the soil; and a portion runs off directly across the ground surface, following available swales and stream channels. In a typical noncoastal watershed, the hydrograph which develops in the stream channel following rainfall is the direct result of overland runoff alone. Timing and shape of the peak of flow downstream in this noncoastal watershed is a function of the soils, steepness of the watershed, and vegetative surface. In a watershed which is underlain by fairly dense rock strata and a correspondingly dense soil mantle, the surface runoff is immediate. The groundwater flow is long delayed, gradually seeping out of storage as "base flow" to maintain the stream long after rainfall.

In the Atlantic coastal drainage region, however, the process of stormwater runoff is quite different. Because the land surface is comprised of unconsolidated sand strata, the infiltration of rainfall is much more rapid and complete This increased component of precipitation soaks into the land surface and then moves quickly to the frequently shallow water table (Figure 7). The increased water level in the ground causes an immediate discharge to surface stream systems, producing a hydrograph which is similar to, but somewhat more attenuated and longer in response time than upland area hydrographs. This coastal hydrograph reflects the far greater importance of the sub-surface flow pathway as compared to the overland flow of stormwater runoff in upland basins.

This distinction in hydrologic response mechanisms is critical for the coastal region. As shown in Figure 6, the direct surface runoff from a typical coastal area in an average year is only 2 inches out of the 45 inch total rainfall (4%), as compared to 10 inches (22%) in a noncoastal drainage basin. The implications of this unique pattern of hydrologic response are extremely important to fully and adequately understand stormwater and stormwater pollution. In the Atlantic coastal drainage, the natural process which exists before the introduction of paved surfaces, rooftops, storm sewers, and altered vegetation and landscape provides a filtration function which usually minimizes, if not prevents the natural and man-made pollutants on the land surface from being carried directly into the coastal waters. With development, we dramatically alter the pathways of runoff, so that the infiltration of rainfall is prevented. Runoff is collected and conveyed in a network of pipes and channels directly to the streams which drain to the marine waters. Along the way, this runoff picks up and carries with it the sediment, fertilizers, hydrocarbons, manmade and natural detritus, and other residual pollutants which characterize the landscape. It is no wonder, then, that we have observed a significant change in the coastal marine environment, especially in those areas where this process of urbanization and hydrologic alteration is most advanced.

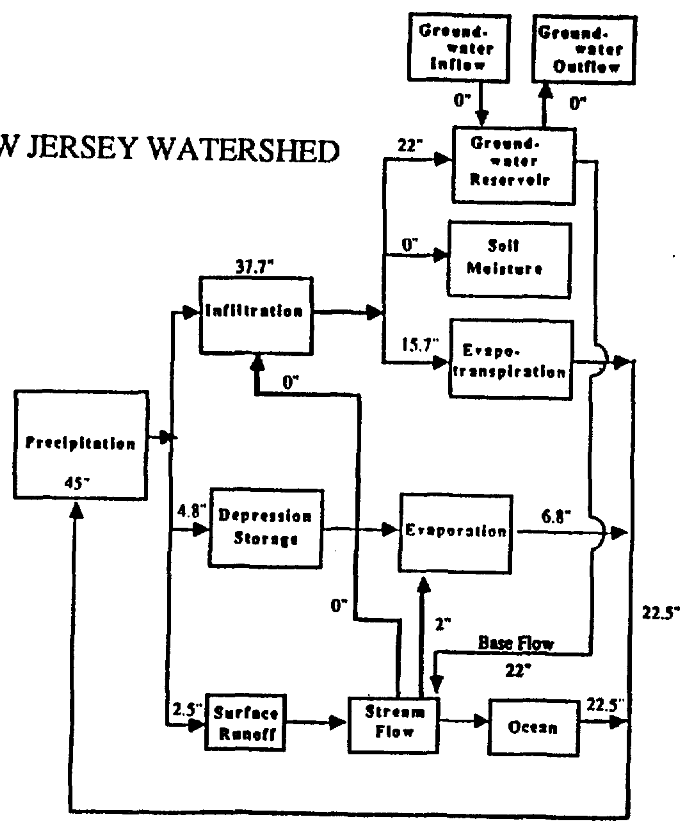
The process of pollutant transport during and as a part of stormwater runoff was recognized during the early 1970's, when studies were conducted which measured the increase in concentration of various pollutants during runoff (Baker, 1973; Cahill, 1974). This body of work generated "chemographs," or changes of pollutant concentration over time and flow rate. These chemographs resembled hydrographs (Figure 8) and had significant implications for water quality. For some pollutants, pollutant concentrations actually appeared to increase during runoff events, in contrast to point source pollutant

TYPICAL UPLAND WATERSHED



AVERAGE ANNUAL WATER BALANCE - MERCER COUNTY

COASTAL NEW JERSEY WATERSHED



AVERAGE ANNUAL WATER BALANCE - COASTAL ZONE

Figure 6. Water Balance Diagrams - Upland and Coastal Basins Annual Rainfall in Inches (Cahill and Associates, 1988)

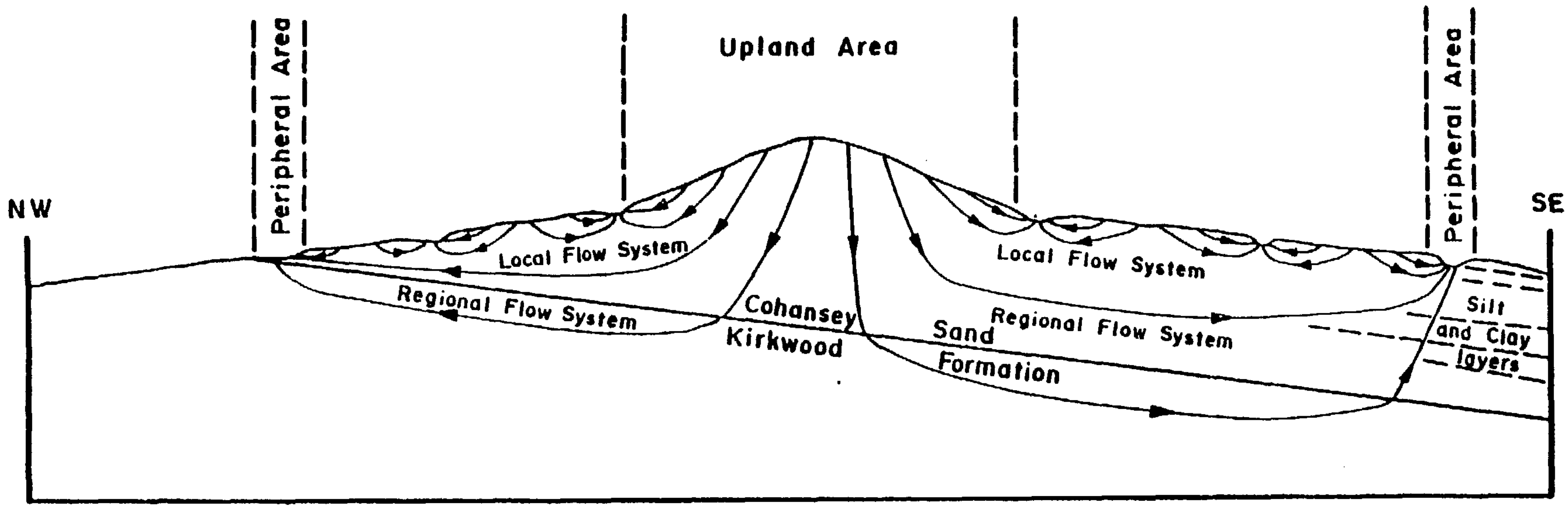
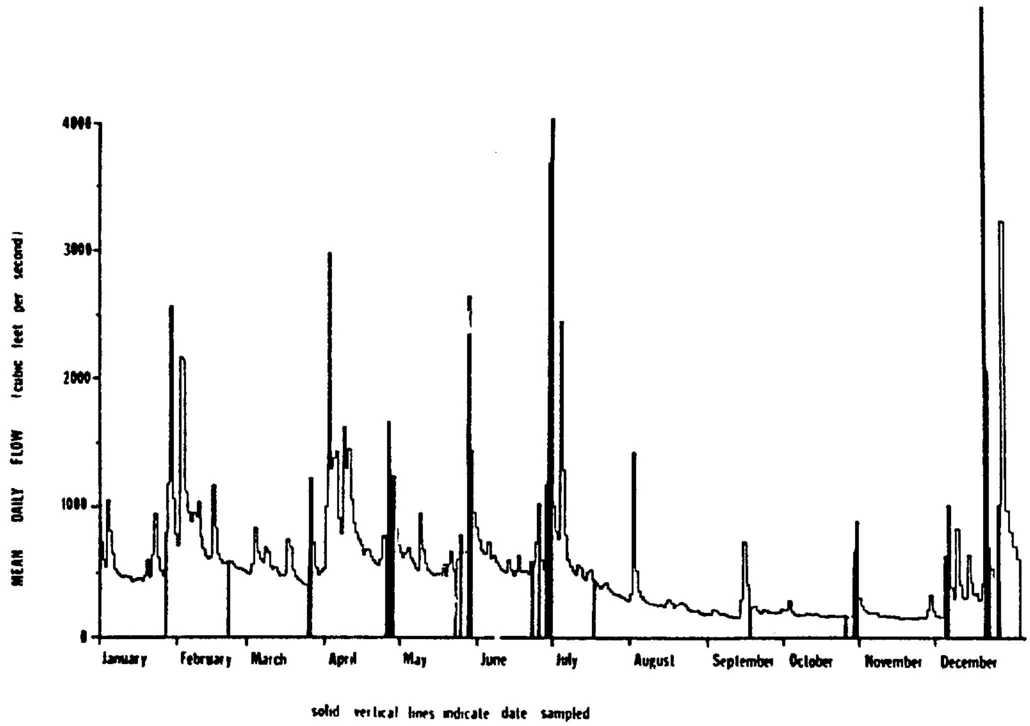
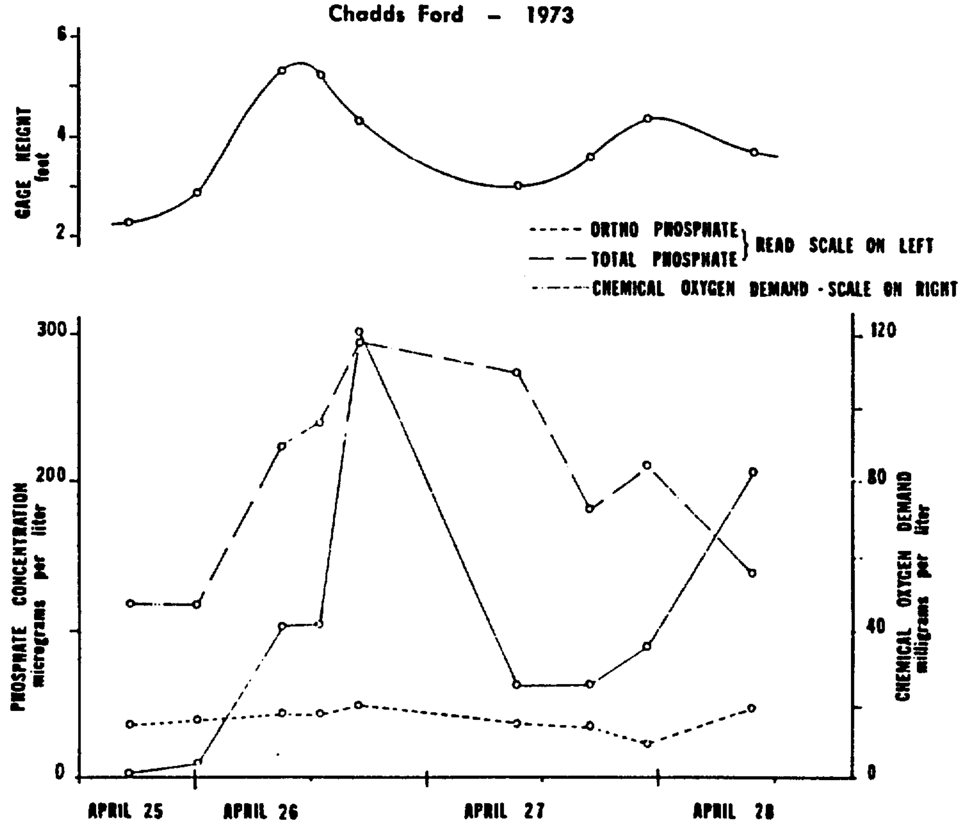


Figure 7. Groundwater Flow Patterns in the New Jersey Atlantic Coastal Drainage (From Rhodehamel, 1970)



Mean Daily Flow
Chadds Ford - 1973



Storm Survey
Chadds Ford - 1973

Figure 8. Chemographs of NPS Pollutant Transport (Cahill et al, 1975)

loadings that would tend to be diluted by storm flows. This meant that the total mass transport of various pollutants through a river system was dominated by the storm runoff cycle. Large-scale studies of systems such as the tributary rivers which drain into Lake Erie (LEWMS, 1977) indicated that as much as 60% of the total mass transport of critical pollutants, such as phosphorus, occurred during stormwater runoff and was not associated with discharges from sewage treatment plants. Thus, the mechanisms of stormwater pollutant transport, their sources and "sinks," and the chemical and physical forms of pollution from land runoff came to be more fully understood and have been the subject of continuing study for some time (USEPA, 1986). In fact, in the reauthorization of the Clean Water Act in 1987, Congress has elevated the priority of nonpoint source pollution problems and has directed EPA to undertake special efforts to manage this mounting pollution source.

In addition to the process of pollutant transport, stormwater has other water quality implications. The net increase in total runoff after development adds to the hydraulic burden conveyed by a stream channel system. This increased flow adds to the pollution load by increased scouring velocities, carving new channels, and transporting sediment downstream (Leopold, 1976; Hammer, 1977).

Lastly, we must also appreciate the fact that the receiving water bodies in the Atlantic coastal drainage, in many cases, are tidally dominated. To the extent that tidal domination exists, increases in stormwater quantity which may result from increased impervious surfaces after development have no real impact on water levels in these zones. In tidally dominated zones, holding the peak rate of runoff constant through the design of stormwater basins and structures is of no consequence hydraulically. That is, there is virtually no flood impact which can be attributed to increased runoff from upland areas. Transitional areas (areas farther upstream where tidal effect is either nonexistent or minimal) do exist where tidal dynamics and riverine flooding effects interact and must be viewed as cumulative in effect. Also, in situations where inland impoundments have created distinct freshwater systems with no hydraulic interconnection with the marine waters, tidal dominance will not be determinative. In these instances, the local runoff can and does have increased flooding impacts. To a considerable extent, however, the focus of stormwater management which historically has driven the formulation of regulation throughout the balance of New Jersey and elsewhere--the attenuation of peak flows of runoff--has reduced relevance in much of the Atlantic coastal drainage.

In summary, the impact of stormwater runoff on coastal water quality is quite different from traditional stormwater management concerns--downstream flooding increases related to increased peak runoff rates--which have guided most stormwater management programs. Because of this uncharacteristic quality, this report is guided by a fundamental axiom:

> **The primary impact of stormwater runoff on coastal waters is the decrease in water quality and not an increase in water quantity which results in flooding problems.**

Ecology of the New Jersey Coastal Marine Environment

In order to understand the nature and extent of stormwater's qualitative impacts on the coastal marine environment of New Jersey, we must first appreciate the delicate ecological balance which exists in this Atlantic coastal drainage. There are distinct habitats which exist in the different elements of this drainage zone, as characterized in Figure 9. The nearshore ocean waters, the embayments, the tidal rivers, wetlands, lagoons and upland tributary streams constitute a series of related but unique ecosystems. The inland drainage of predominantly groundwater to surface streams produces a very high quality (although typically acidic) aquatic environment in the riverine ecosystem, with its own special set of conditions and constraints (Durand, 1980). As this drainage approaches the coastal fringe, it is impounded in many small lacustrine systems, which serve as both temporary and permanent nutrient sinks, significantly changing the biochemical processes in the aquatic system. The inland freshwater flows from both surface streams and groundwater seepage then drain into the brackish waters of the estuary's back bays, semi-enclosed bays (or lagoons), tidal guts, and coastal wetlands, mixing to create yet another aquatic ecosystem. The hydrodynamics of this estuarine system, with a decrease in velocity, subsequent settling of particulate matter, and tidal mixing, become extremely important in the biochemical processes which take place. Finally, the displacement of these brackish waters into the ocean with each tidal cycle completes a hydrologic transport of chemicals, many of which have changed form as biomass (and in fact may have changed form several times) through the total coastal drainage cycle.

An important measure of any ecological system is the rate of primary productivity, defined as "..the rate at which radiant energy is stored by photosynthetic and chemosynthetic activity of producer organisms (chiefly green plants) in the form of organic substances which can be used for food materials." (Odum, 1971). This can also be expressed as the chemical equation:

$$6\,CO_2 + 6\,H_2O \text{ -->(light) --> } C_6H_{12}O_6 + O_2$$

The marine ecosystem comprises the greater share of total productivity in the biosphere, and the estuaries and nearshore zones within this marine ecosystem are the most productive on a unit area basis (Curie, 1958; Odum, 1972; Clark, 1977; Figure 10). The food chain that has evolved in the estuaries and coastal waters offers tremendous variability; because of this availability of food, coastal waters in a relatively undisturbed state literally teem with life. States Clark (1972):

> "The life cycle of the estuary begins with plant life--marsh grass, mangroves, submerged bottom plants or masses of drifting phytoplankton (frequently present in concentrations of millions per quart of water). Some of the plant material is consumed directly by shellfish and fish but more often it is eaten directly by the zooplankton (tiny floating animal life) which in turn become the food of fishes, and they in turn are consumed by birds or people. This transfer of food energy from lower to higher forms, known as the food chain or food web, is comprised of a number of separate components. The plants are the producers. Smaller plant-eating animals, known as consumers (or herbivores), feed on the phytoplankton or, to a lesser extent, on the larger plants. Others are foragers, those that prey directly on the consumers, and others are predators, those that prey on the foragers. A few species, including the finest game fish, are super-predators that pursue and capture smaller predators....Finally there are the decomposers, bacteria that reduce dead matter back into basic minerals.
>
> "Many species change their feeding habits dramatically, utilizing different parts of the food chain as they grow from larvae to post-larvae to juveniles to adult fish....
>
> "Rooted plants are vital in the food system of estuaries....For example, in the tideland marshes or mangrove forests, as the grasses die or the mangrove leaves fall, the decaying plants create organic detritus, small organic particles which are

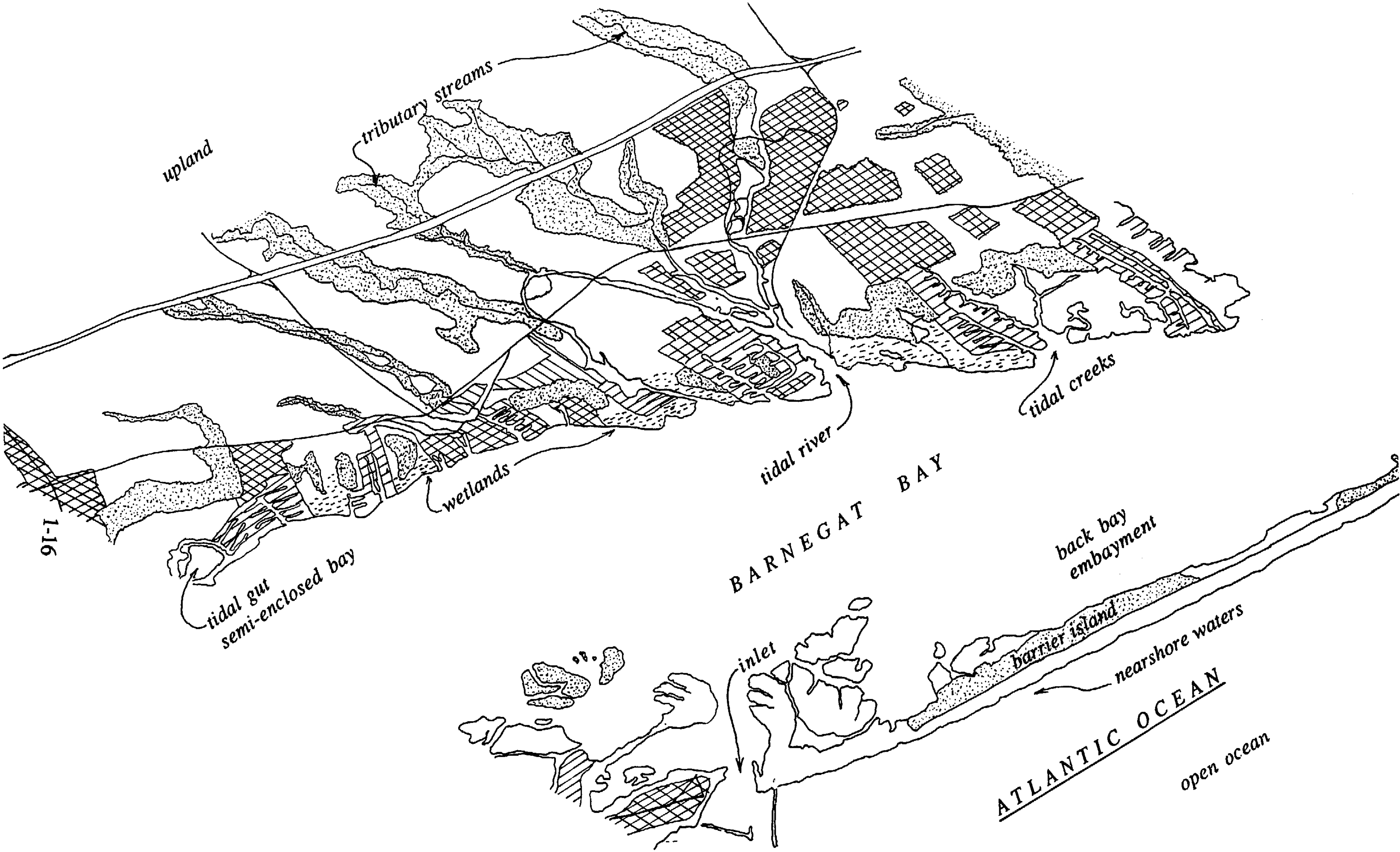


Figure 9. Coastal Zone Habitats (Cahill and Associates, 1988)

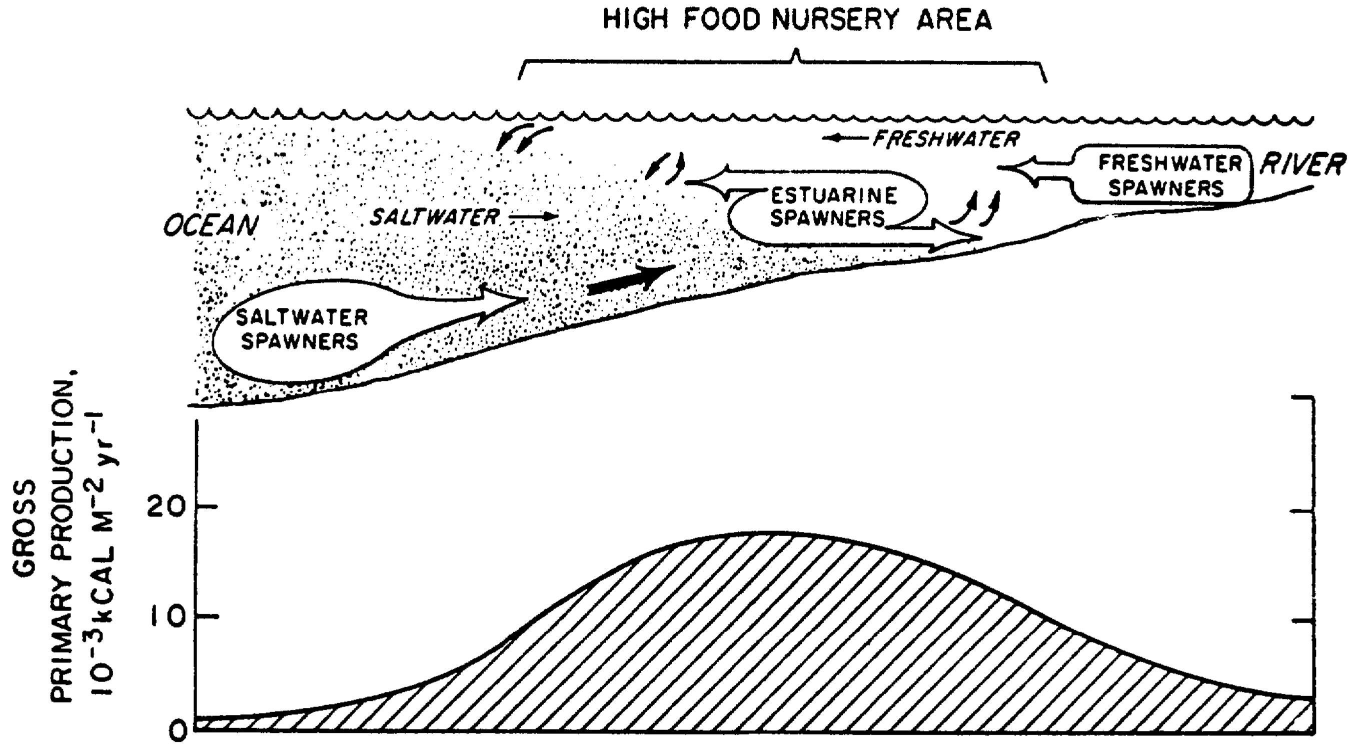


Figure 10. Primary Productivity in the Coastal Drainage System (Clark, 1977)

spread by waterflow throughout the ecosystem to become an important nutrient element in the diet of many species. Beds of submerged grass--eel grass, etc.,--also produce the valuable detritus.

"Much of the protein food of smaller aquatic animals is derived from digesting the bacteria and other microorganisms that live on floating particles of detritus. The detritus is swallowed, the bacteria are digested, and the particles are passed back to the water where new layers of bacteria will form to nourish more animals. The essential role of the abundant bacteria is to continually decompose dead plants and animals and thus reduce their basic constituents to basic minerals--nitrates, phosphates, etc.--which provide the nutrient supply for a new cycle of plant life. There is a continuous loop.

"This continuous removal of phytoplankton, zooplankton, and detritus into the food web is an effective method for storing the nutrients that flow through the estuary."

In the coastal waters of New Jersey, we are dealing with an extremely productive ecosystem. As described by Pearce (1980):

"The coastal shelf waters being investigated are among the most productive in the world. Primary production through photosynthesis averages 150 grams of carbon per square meter per year..." (gC/m2/yr.)

Other more recent estimates (SAIC, 1986), as summarized in the "Green Tide Environmental Inventory," report much higher productivity in these waters:

"Recent data from the nearshore Middle Atlantic Bight and the New Jersey nearshore (0-20 m) regions clearly document high rates of primary production (above 500 g C/m2/ yr.) that are much greater than the mean annual production for the continental shelf of the New York Bight (about 300 g C/m2/yr.) Anthropogenic nutrient loading and non-point source runoff from the New Jersey coastal zone undoubtedly contribute to such high rates of primary production..."

Whatever the geomorphological conditions, salinity, or currents, every part of the coastal marine environment plays an important part in the overall productivity of the system and the community of higher organisms, such as finfish and shellfish, which man has harvested for centuries (Figure 11). The disruption or imbalance of this system is manifested in decreased fish harvests, depleted or contaminated shellfish beds, or the excessive growth of certain components of the food chain, such as algae.

System balance is critical. What is essential in limited quantities, such as nutrients and trace metals, will create pollution when in excess concentrations.

Unfortunately, our knowledge of many aspects of this complicated system is imperfect. Many critical questions--such as what is the ideal level of chemical constituents, both nutrients and food sources, which will maintain the natural balance and productivity of the marine ecosystem without exceeding the tolerance limits--have yet to be answered adequately.

Throughout the marine ecosystem's major hydrologic and biochemical sub-systems, the conditions of water circulation and currents, depth, nutrient availability, and other physical and biochemical parameters define different micro-environments which are unique to

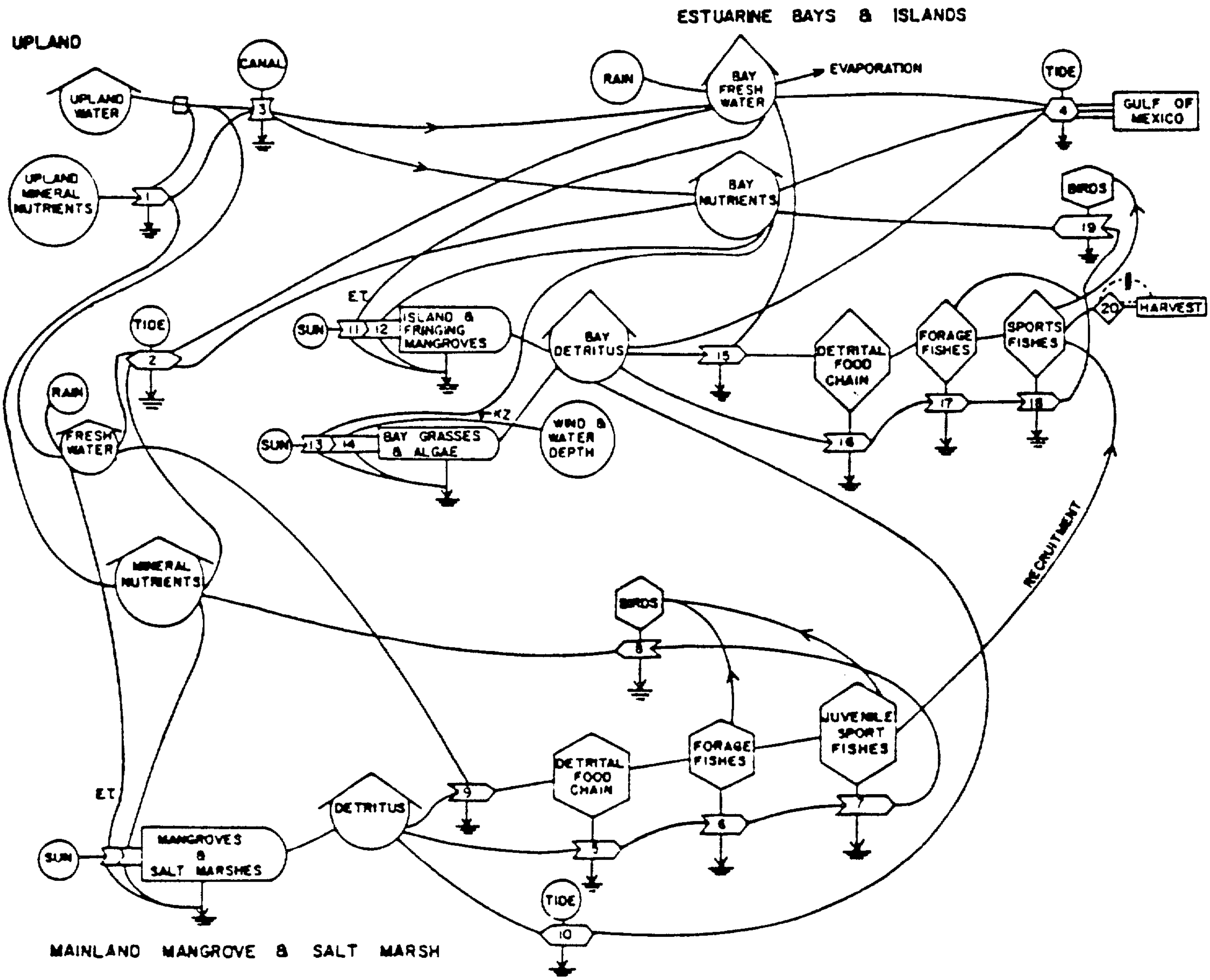


Figure 11. Model of Typical Estuary Ecosystem (Clark, 1977, from Carter, et al, 1973)

Atlantic coastal drainage (Figures 12 and 13). Each part of the coastal ecosystem--each distinct phase of the environment--is more or less sensitive to the mix of natural and manmade pollutants which are flushed into the aquatic system by stormwaters from adjacent uplands, as well as contributed from direct rainfall. Although these distinct micro-environments exist, there is a sense of continuity throughout the total marine ecosystem, in that the presence or accumulation of various pollutants in any one phase ultimately will carry through and effect the balance of the entire coastal water quality system.

As stated above, the ecology of the Atlantic coastal drainage is reflected in the various types of surface vegetation which are supported by and in turn chemically process the constituents in flowing waters. This terrestrial ecosystem is dominated by wetlands, which are in turn categorized by the aquatic system which supports them (Figure 14). These various wetlands comprise a significant portion of the 1,750 square-mile drainage area within the Atlantic coastal drainage (Figure 15). Their role as an intermediate ecosystem which influences the resultant water quality in the bays and estuaries cannot be underestimated, and, as has been acknowledged for some time, their loss or destruction would eliminate a vital component of the biochemical process. Those wetlands, for example, which are situated downgradient from development can and do function as filters and pollutant removal systems for coastal stormwaters. Therefore, it is of special importance that rigorous programs have been established on both the State and Federal levels to protect both freshwater and coastal wetlands. These wetlands policies are reinforced by various policies in the coastal permitting program (Sections 3.25 "Wetlands" and 3.26 "Wetlands Buffer", for example). The question to be considered in the context of this report is whether the role of wetlands should be expanded, such as by intentionally diverting runoff into such systems, achieving some additional measure of pollutant removal and considering them to be a part of the stormwater treatment process. We also might create new "artificial" wetlands in areas contiguous to existing systems, and add to the natural buffer. This issue of wetland use and expansion has been a subject of active debate within the Department (NJDEP, 1988), and has both positive and negative implications, as discussed further in this Manual.

Present Water Quality in the Coastal Region

One would expect that any water system as extensively utilized as the Atlantic Ocean coastline, the adjacent estuaries, back bays, major rivers and streams within the Atlantic coastal drainage would be well documented scientifically, with considerable existing information on ambient water quality and water quality trends. In fact, the record of water quality sampling, analysis, and evaluation for coastal estuaries and ocean waters is relatively recent and fairly incomplete. The body of actual data contained in computer files, such as STORET, consists primarily of bacteriological sampling, with a limited amount of near shore water quality analyses reflecting nutrients, organics, and other pollutants. Inland sampling stations contain some anion and cation data, and special studies conducted by state and local agencies and academic institutions provide fragments of selected information. Considering the coastal region as a whole, however, the record is quite limited. There has not been developed a comprehensive record of water quality, measuring the temporal and spatial variability of key parameters, throughout the various components of the Atlantic coastal drainage system. Thus the discussion of current water quality is limited to those parameters for which some data exists, even though the concerns expressed in following sections address a much broader spectrum of pollutants.

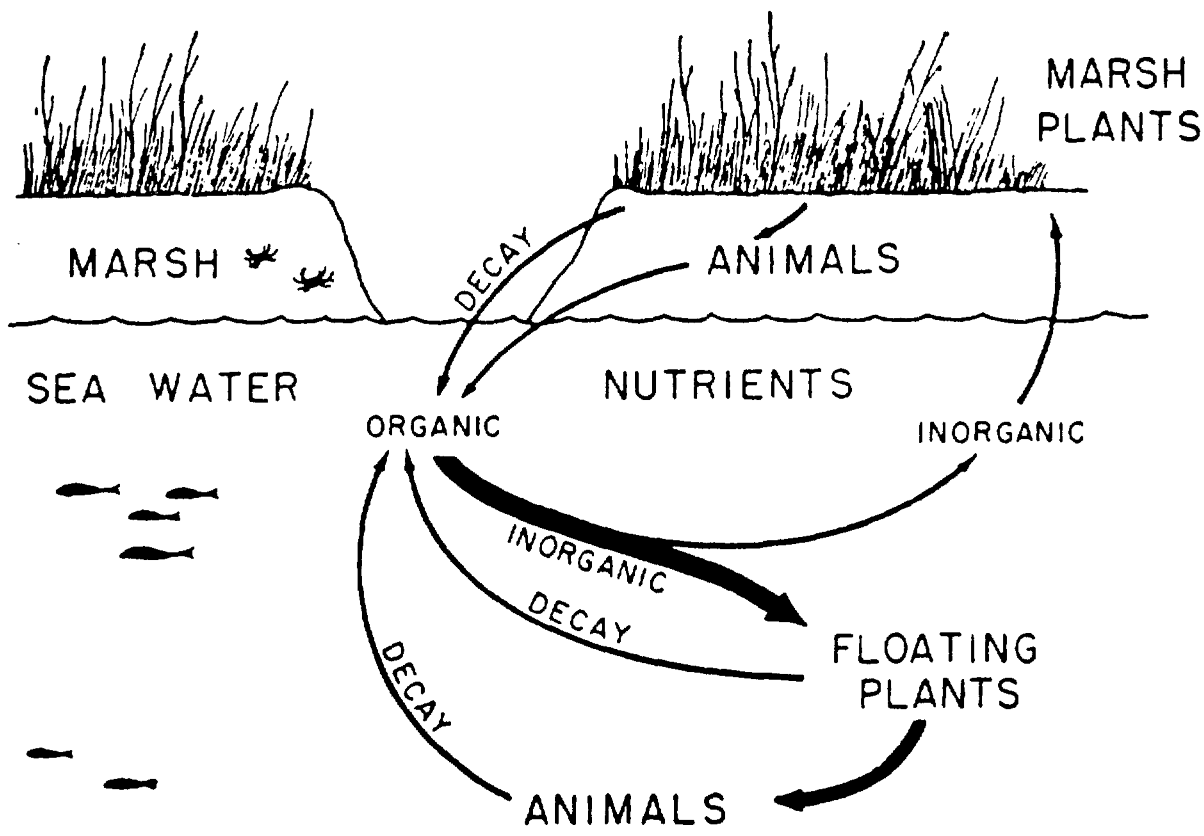


Figure 12. Nutrient Cycling in a Brackish Marsh (Clark, 1977)

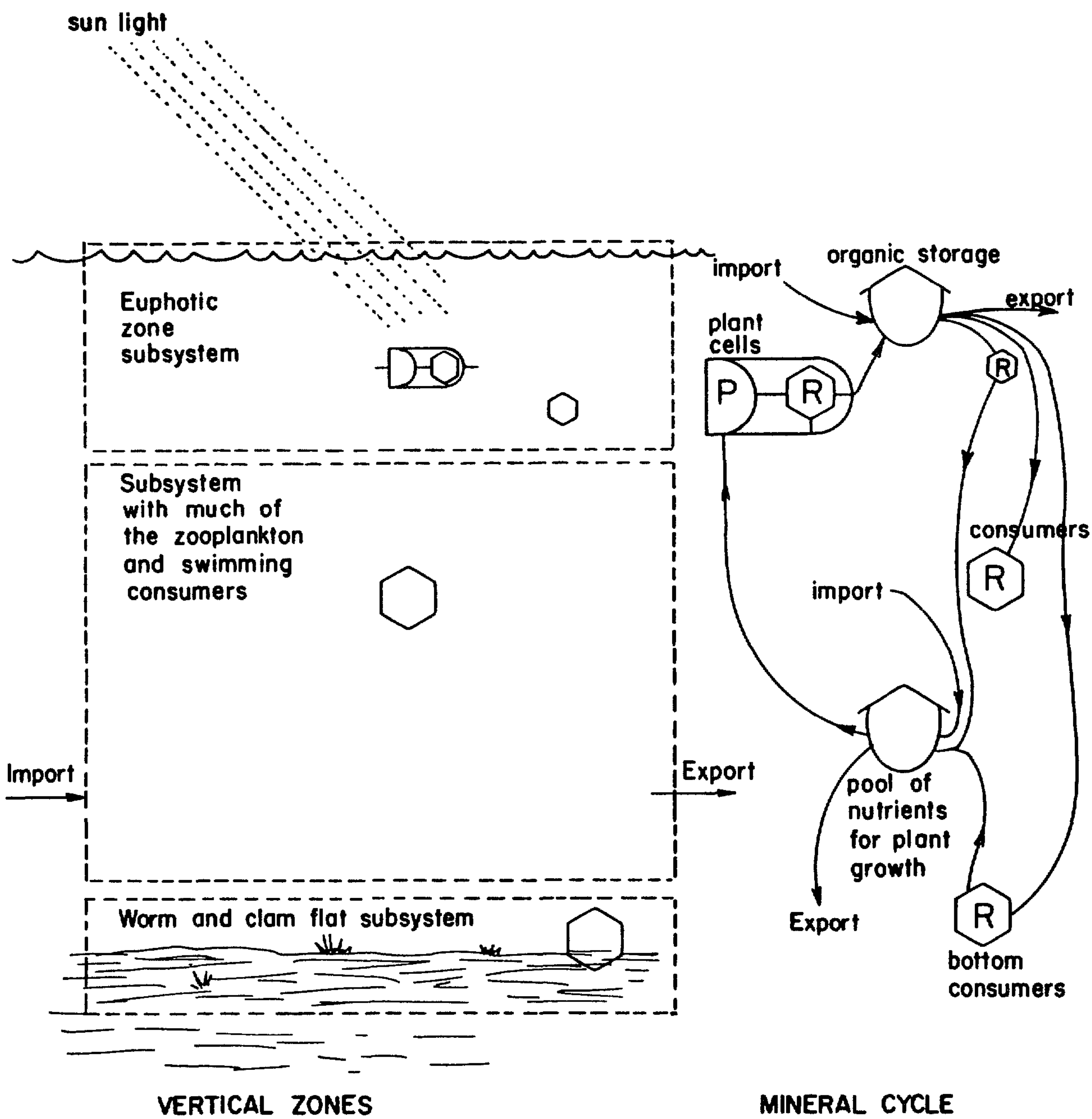


Figure 13. Productivity in a Coastal Back Bay (Odum, 1972)

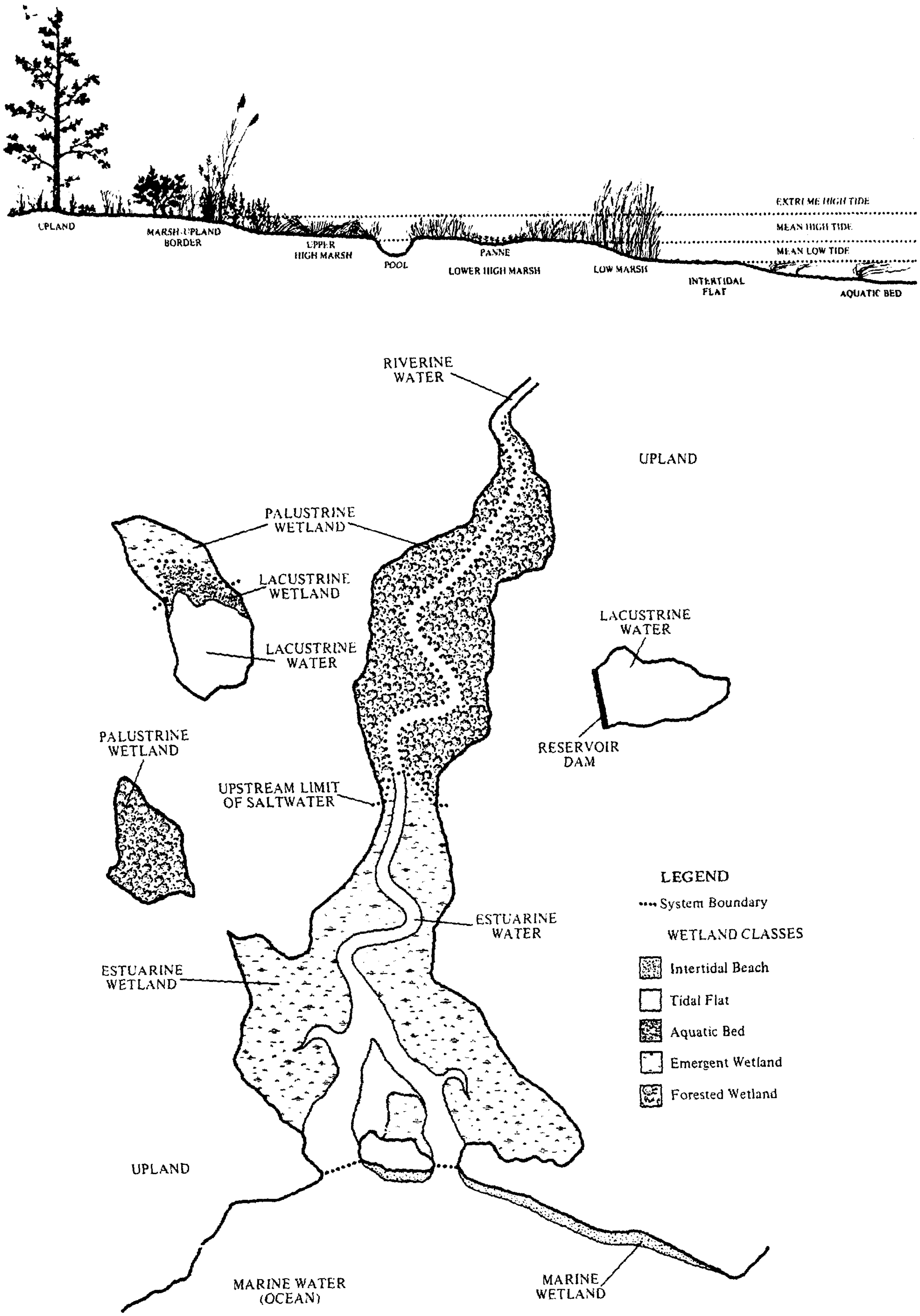


Figure 14. Types of Wetlands in the New Jersey Atlantic Coastal Drainage (USDOI, Fish & Wildlife Service, 1985)

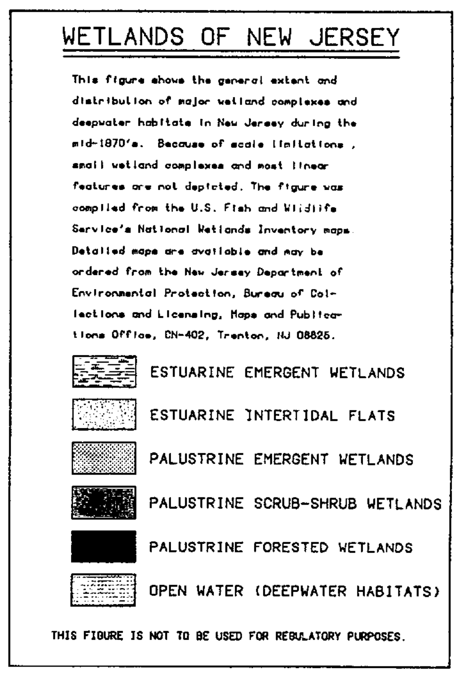


Figure 15. Wetlands of New Jersey (USDOI, Fish & Wildlife Service, 1985)

That is not to say that the various Federal and State Agencies who play various roles with respect to monitoring the relative state of water quality here have neglected to do what is mandated under current water quality statutes and regulations. Nevertheless, it is a painful fact that much more homework is necessary before definitive scientific conclusions can be made as to the current state of water quality in this complex aquatic system, or set of systems. We are compelled to point out that the use of labels such as "good" or "fair" to describe ambient water quality in different reaches of the Atlantic coastal drainage is not especially meaningful. System dynamics create a set of conditions which is constantly changing. Therefore even the most simplistic water quality measurements should be continuous over space and time, criteria which have seldom been met with respect to existing data.

> **There is a surprising lack of water quality data in the Atlantic coastal drainage. Therefore, it is less than surprising that we fail to understand so many of the cause-effect linkages in this system or set of systems.**

Furthermore, we do not understand fully the workings and interrelationships of the myriad elements of this aquatic system. More importantly, we have only begun to define precisely those water quality improvements which can be accomplished by imposing management programs which target specific pollutant sources, such as wastewater discharges, sludge dumping, or nonpoint source pollutants. In short, the cause and effect relationships of most water quality problems have not yet been authoritatively established in the Atlantic coastal drainage.

> **However, it is apparent from the current state of scientific knowledge, from the accumulation of studies and partial information which has been collected to date that a substantial portion of the observed water quality problems in the coastal waters are directly related to the pollutants conveyed by stormwater runoff.**

To explain this conclusion we begin with an understanding of those specific water quality problems which have been experienced in different coastal waters. We then consider which pollutants are primarily responsible for these water quality problems, in so far as the available record allows. We must also point out here that, in the interest of brevity, we have tried to steer clear of several major issues such as ocean disposal of sewage sludge and the Army Corps of Engineers disposal of dredge spoil, which have important water quality ramifications, but which are not at issue here. These problems are being dealt with by other agencies in other programs. Similarly, we have not detailed the array of municipal and nonmunicipal point source discharges within the Atlantic coastal drainage. Again, there is a complex regulatory program with an enforcement element (delegated from EPA to NJDEP) for these point source discharges which is already in place. These programs are far from perfect, but they do exist, are having results, and can be expected to continue to make water quality progress in the years ahead.

As partial as the data might be, this document does not reprint the water quality data record which does exist. The NJDEP and EPA data on bacteria, the array of special studies on the various algal bloom events, data from the in-place monitoring stations on the rivers and streams within the Atlantic coastal drainage area as part of NJDEP's ongoing monitoring program (as reported in various 305b reports), data from county health departments which perform their own monitoring programs, and other special studies would overwhelm this Manual. Alternatively, the discussion here focuses on those several issues which bear most directly on water quality issues at hand.

Dissolved Oxygen: For some parameters, such as the concentration of dissolved oxygen (DO) in the near shore ocean waters during the summer, the past ten years of data show a distinct pattern of anoxia (or oxygen depletion) in certain regions (Figures 16 and 17). The root cause of that condition is still subject to scientific debate (EPA, 1987). Certainly, we have sufficient knowledge of water biochemistry to recognize that this oxygen depletion is attributable to the decomposition of organic material. The primary source of that biomass is the excessive growth of various forms of zooplankton and phytoplankton. The occurrence of this excessive algal growth is a problem in itself, producing the visible and esthetic conditions known as "green," "brown," and "red" tides (USEPA, 1986; USEPA, 1987), depending on which specific form of algae dominates the bloom. However, the linkage between enrichment by nutrients and dissolved oxygen depletion makes this specific water quality problem complex, since the decomposing biomass may originate within embayments or grow directly in the enriched nearshore waters. Thus the nutrients drive the system to excess, and the stress is experienced by a depletion of DO.

Nutrients--Phosphorus and Nitrogen: The dynamics behind dissolved oxygen fluctuations are not always obvious. We know that low dissolved oxygen levels in bottom waters can severely stress or kill marine life. We know that algal blooms (with the associated proliferation of jellyfish) can directly cause depressed DO levels. We also know that the pollutants which drive the biochemical processes are the nutrients, phosphorus and nitrogen. The relative importance of these two nutrients in the excessive enrichment of coastal waters is a subject of continuing debate in the scientific community, turning on which specific chemical nutrient may be "limiting" in a biochemical sense (Liebig, 1840). This concept of "limiting" is important because if management plans are to be effective and reduce the occurrence of excessive algae growth and other enrichment problems, the plan must be able to correctly identify and reduce the critical or limiting nutrient. For inland fresh water systems which have experienced the occurrence of excessive nutrient enrichment, known as "cultural eutrophication" because of the anthropogenic nature of the nutrients added to the aquatic system, there is an overwhelming body of scientific data which demonstrates that phosphorus is the "key" or limiting nutrient. However, the study of coastal marine waters has indicated that they are naturally low in concentrations of nitrogen (NJDEP, 1985) in a form which is readily available for biological uptake (i.e., as nitrate or ammonia), and so it has long been believed that in marine systems, nitrogen is the key nutrient to "manage" (Ryther, 1971; Durand, 1977). Recent study (Lee and Jones, 1987) has proposed that in certain phases of the coastal marine environment, such as the waters which flow from the Hudson and Raritan estuaries into the coastal marine system known as the New York Bight, the concentrations of available phosphorus from numerous wastewater discharges could play a significant role in the excessive algae growths experienced in these waters. In the coastal waters further to the south along the New Jersey coast, the algae blooms experienced during the past ten years have been attributed to nutrient discharges from both partially treated wastewaters discharged by coastal communities, nutrient fluxes from embayments into the shore waters, and upwelling of enriched nearshore bottom waters.

In a sense, the issue of how much of the problem is attributable to stormwater runoff is secondary to the problem of which of the two nutrients should be the focus of management strategies in stormwater systems. The sources of both nutrients in stormwater are similar, but their chemical form and transport through the stormwater drainage system is quite different. A management program which focuses solely on phosphorus in particulate form or nitrogen in dissolved form, for example, would recommend different strategies and follow different techniques. Chapter Three discusses the differences in these two critical pollutants, as well as the various other pollutants of concern in stormwater runoff. Chapter Four introduces a set of management techniques which address both of these pollutants and

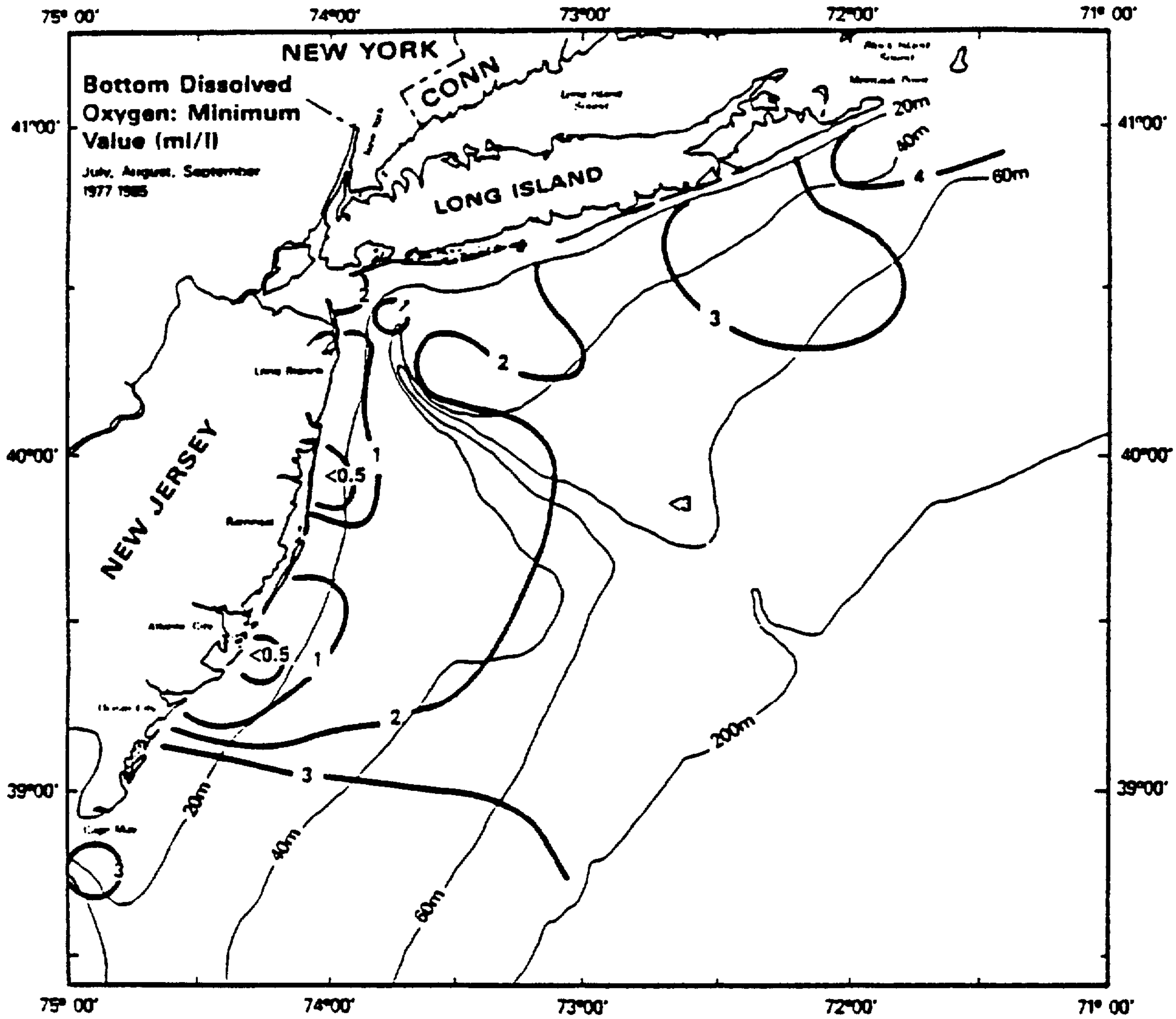


Figure 16. Anoxia Patterns in the New York Bight, 1976
(J. E. O'Reilly, unpubl., 1985)

Dissolved Oxygen Concentration Profiles

New Jersey Coast

August 1985

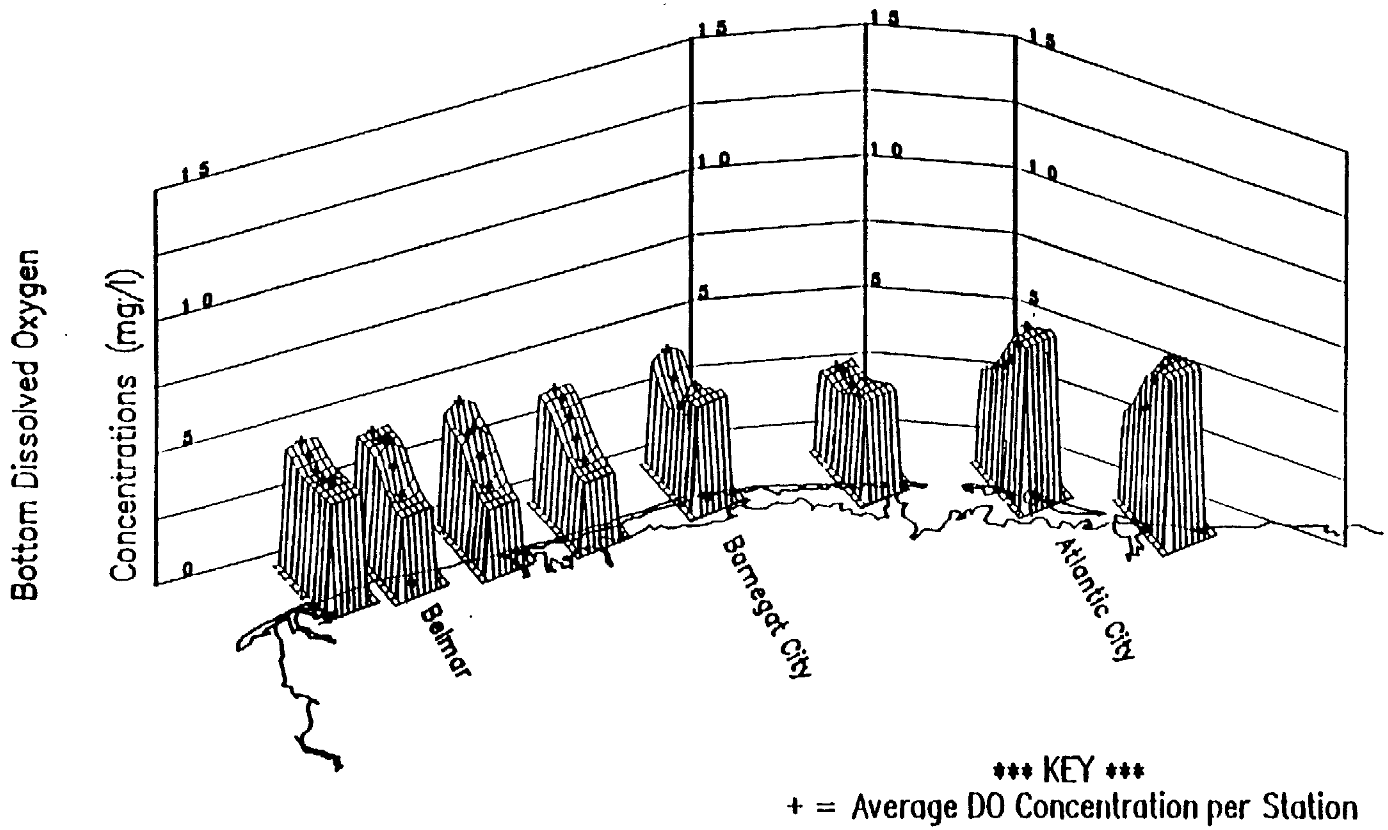


Figure 17. Dissolved Oxygen in New Jersey Coastal Waters - 1985 (USEPA, 1987)

their relative effectiveness in reduction and removal of nitrogen and/or phosphorus from stormwater.

Excessive enrichment of the Atlantic coastal drainage is not the only water quality problem resulting in part from stormwater discharges. However, the land management and stormwater control systems recommended in this Manual which are appropriate to reduce the transport and discharge of nutrients to coastal waters will also be highly effective in reducing a number of other pollutants which are of concern. In Chapter Three, a set of recommended water quality standards for stormwater discharges is discussed (Table 19), and a rationale is provided for each parameter or group of parameters. The degree of effectiveness in reducing these various pollutants by different techniques is discussed in Chapter Four. Much of this discussion, we believe, hinges on the critical differentiation between two groups of pollutants--particulate and soluble. In dealing with the soluble forms of nitrogen and the particulate forms of phosphorus, we are effectively designing a water treatment process which will remove a whole spectrum of pollutants from stormwater prior to discharge into coastal waters.

Bacteria: The available scientific data (STORET, 1988) describing ambient water quality in the ocean portion of the Atlantic coastal drainage is primarily focused on the near shore ocean waters. The measurement of quality in these waters largely has been accomplished through the use of indicator groups of microorganisms or bacteria. The reason for this approach is quite simple--the water uses of concern from a public health standpoint are primary contact recreation in the beach areas and ingestion of shellfish and finfish. Both uses have had long-standing water quality criteria, measured in terms of the density of the coliform bacteria present in the water. The suitability and applicability of this criterion to evaluate overall water quality conditions and problems in coastal waters has been the subject of considerable discussion (NJDOH, 1988).

> "A consensus among public health scientists as to the best indicator organism or organisms for judging the quality and acceptability of fresh and marine recreational waters is not evident....Three main opinions as to what should be done about the indicator systems emerge....
> 1. Microbiological quality of fresh and marine waters, including swimming pools, is best measured by using bacteria that indicate fecal contamination, such as coliform or fecal coliform bacteria or enterococci.
> 2. The risk of infection is associated more with microorganisms derived from the skin, mouth, and upper respiratory tract of bathers rather than fecal contamination so that water quality sampling should address these organisms, and
> 3. Microbiological standards with any indicator group of bacteria are virtually impossible to construct and are meaningless measures upon which to base public health decisions such as closing beaches."

As imperfect as the system might be, public health officials at both the State and local government levels appear to believe that the current techniques and criteria based on a fecal coliform (FC) concentration of less than 200 colony forming units (CFU) per 100 milliliters of water are valid indicators of ambient water quality for the defined uses (NJDOH, 1988). The USEPA has proposed a standard of 35 CFU/100 ml. for enterococci, a sub-group of fecal streptococci, based on studies which indicate a better correlation with human illness (Cabelli, 1983). Whatever the yardstick, the use of indicator microorganisms rather than any specific pathogen has been and probably will continue to be the basic measure of water quality. This bacteriological data, collected by NJDEP as the part of the Cooperative Coastal Monitoring Program (over 160 ocean and 144 back bay sampling locations) and by EPA's helicopter runs (40 ocean sites, sampled once per week during warmer months), will continue to comprise the vast bulk of available water quality information in coastal waters.

The DEP Cooperative Coastal Monitoring Program has identified stormwater runoff as a probable source of microbial contamination of swimming beaches, noting significant increases in the measured indicator organisms following heavy rainfall (Figure 18).

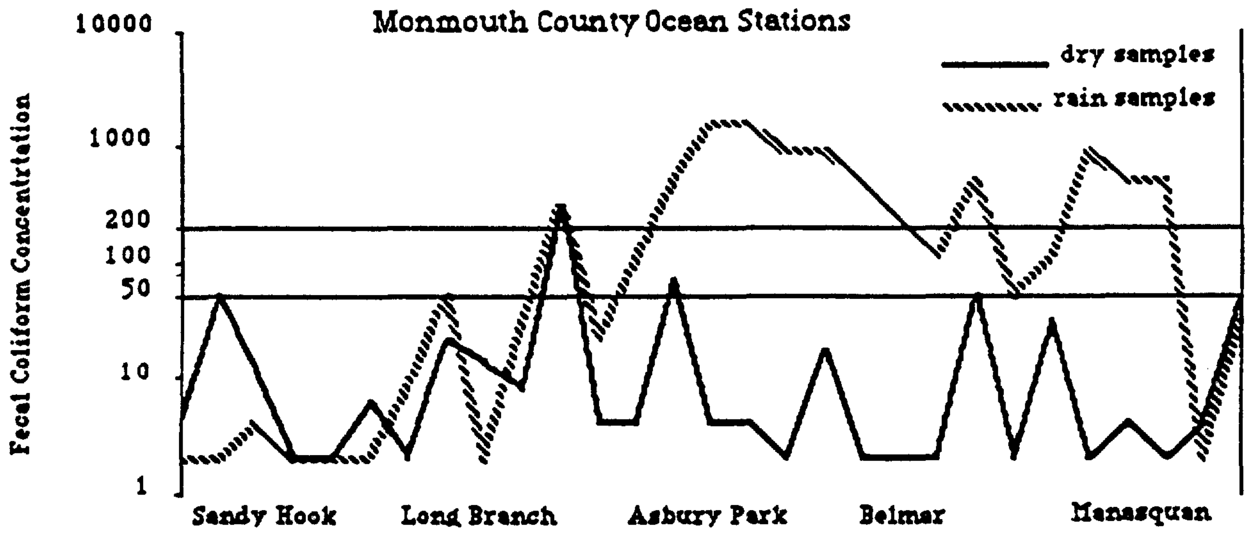
> "Eighty to ninety percent of the coastal beach closings are attributable to localized sources of elevated bacterial pollution from stormwater runoff. During the past two summers there have been no pollution incidents resulting from sewage treatment plants along the coast. The bacteria comes from leaky sanitary sewer lines, cross connections of sanitary lines into storm sewers and pet droppings. Agricultural bacterial loadings from upstream manure piles have resulted in shellfish contamination and closure of shellfish harvesting in back bay areas. Excess fertilizer runoff from agricultural lands and suburban lawns contribute the nutrients that sometimes trigger blooms of algae in the ocean (the so-called red tides, green tides, and brown tides). The majority of floating litter and debris that has plagued the beaches of New Jersey comes from stormwater runoff and flushing of storm water pipes after heavy rainfalls."
>
> ("New Jersey's Coastal Ocean," NJDEP, 1988)

The NJDOH reports over 100 storm pipes discharging along the coastline from Sandy Hook to Cape May (Figure 19), excluding those which discharge to the back bays from the barrier islands and the mainland. In addition, 15 major STP's discharge a dry weather effluent flow of 126 MGD (Table 2) to the near shore environment via outfalls which vary in length from 235 ft to 1,500 ft. (Figure 20). At present, several studies have summed up the point source contribution to the nearshore ocean waters from both major and minor (less than 1 MGD) STP's during dry weather flow (NOAA, 1987; Table 3). However, there has been no quantification of the total organic loading from stormwater discharges, including the stormwater which infiltrates into and may overload the sanitary sewer infrastructure.

The leakage of stormwater into sanitary sewer system components with resultant hydraulic surcharging during high water table periods, as well as the illegal interconnection of sanitary wastewaters into storm sewer systems, only serve to complicate the situation further. To prevent the occurrence of unacceptably high levels of indicator microorganisms in ocean and bay waters, it is not yet clear if we should improve the sanitary sewage collection systems, improve the STP's and their effluent discharges to the ocean, or directly treat stormwaters with disinfectants, destroying microorganisms which might include pathogens. In fact, all three measures may eventually prove to be necessary.

If the concentration of indicator groups of bacteria in coastal waters has served as our primary (and some might suggest our exclusive) measure of water quality, what then does this bacteria problem have to do with the excessive growth of algae along the coastline? Are these two conditions related? Will strategies to correct over-enrichment and dissolved oxygen problems reduce bacterial contamination? Scientific study of water quality within the Atlantic coastal drainage has examined a number of individual issues. However, in very few instances have studies considered all of the elements of water quality in a comprehensive fashion, explaining the interrelationships among and between pollution incidents.

Rarely has our work enabled us to understand the multiple causes and effects of individual pollution problems. Most likely, high levels of coliform organisms are related to the



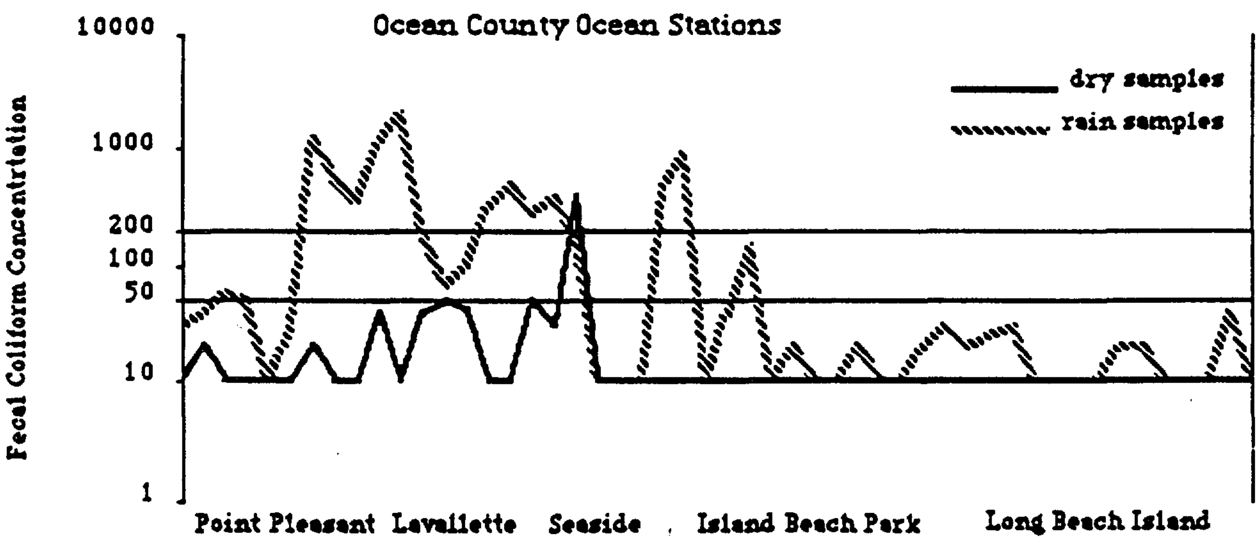


Figure 18. Increases In Fecal Coliform Levels With Stormwater Runoff (NJDEP, 1988b)

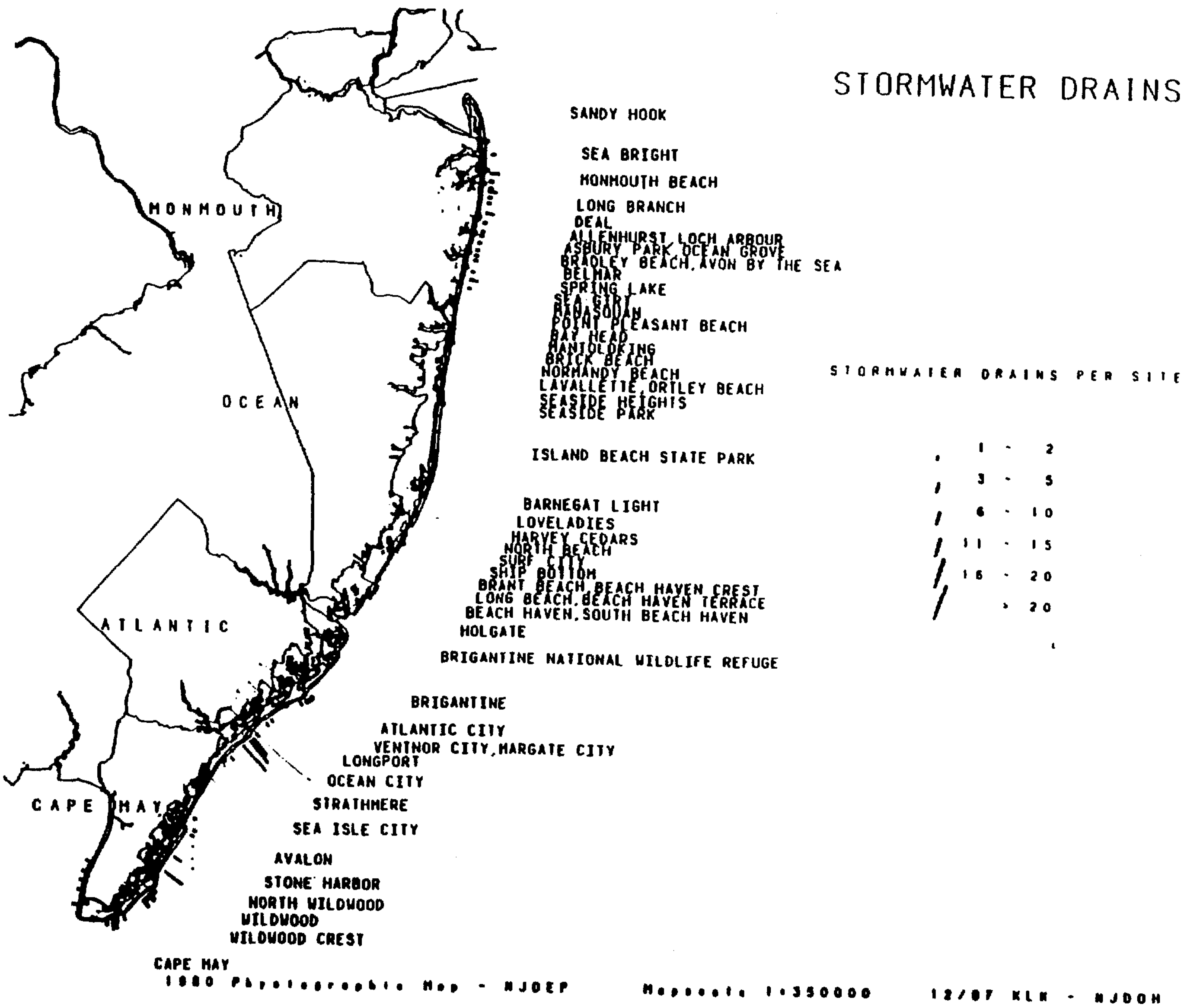


Figure 19. Major Storm Sewer Outfalls in the New Jersey Coastal Zone (NJDOH, 1988)

TABLE 2.

Atlantic Coastal Drainage Sewage Treatment Plants with Ocean Outfalls (NJDOH, 1988)

Site	Outfall length	Diffuser length	Type	(dry) mgd
1. Monmouth Co. Bayshore Regional Outfall Authority	4000'		2nd	15.
2. Northeast Monmouth Regional Sewerage Authority	980'	1500'	2nd	7.5
3. Long Branch Sewerage Authority	1927'	280'	2nd	4.5
4. Deal Borough	1000'		2nd	0.8
5. Ocean Township	1800'	235'	2nd	4.5
6. Asbury Park	1500'	400'	2nd	3.4
7. Neptune Township Sewerage Authority	5000'	1000'	2nd	5.5
8. South Monmouth Regional Sewerage Authority	5000'	1000'	adv 2nd	6.0
9. Ocean County Utilities Authority Northern	5000'	1464'	2nd	13.
10. Ocean County Utilities Authority Central	7000'		2nd	18.
11. Ocean County Utilities Authority Southern	4520'	1480'	2nd	7.
12. Atlantic County Utilities Authority	7710'	1000'	2nd	30.
13. Cape May County Municipal Utilities Authority	6081'	510'	2nd	6.
14. North Wildwood	5000'	530'	2nd	2.8
15. Cape May Municipal Utilities Authority	500'		2nd	2.2

* Source: New Jersey Department of Environmental Protection, 1987

126.2 mgd = 460.6 mgy x 100

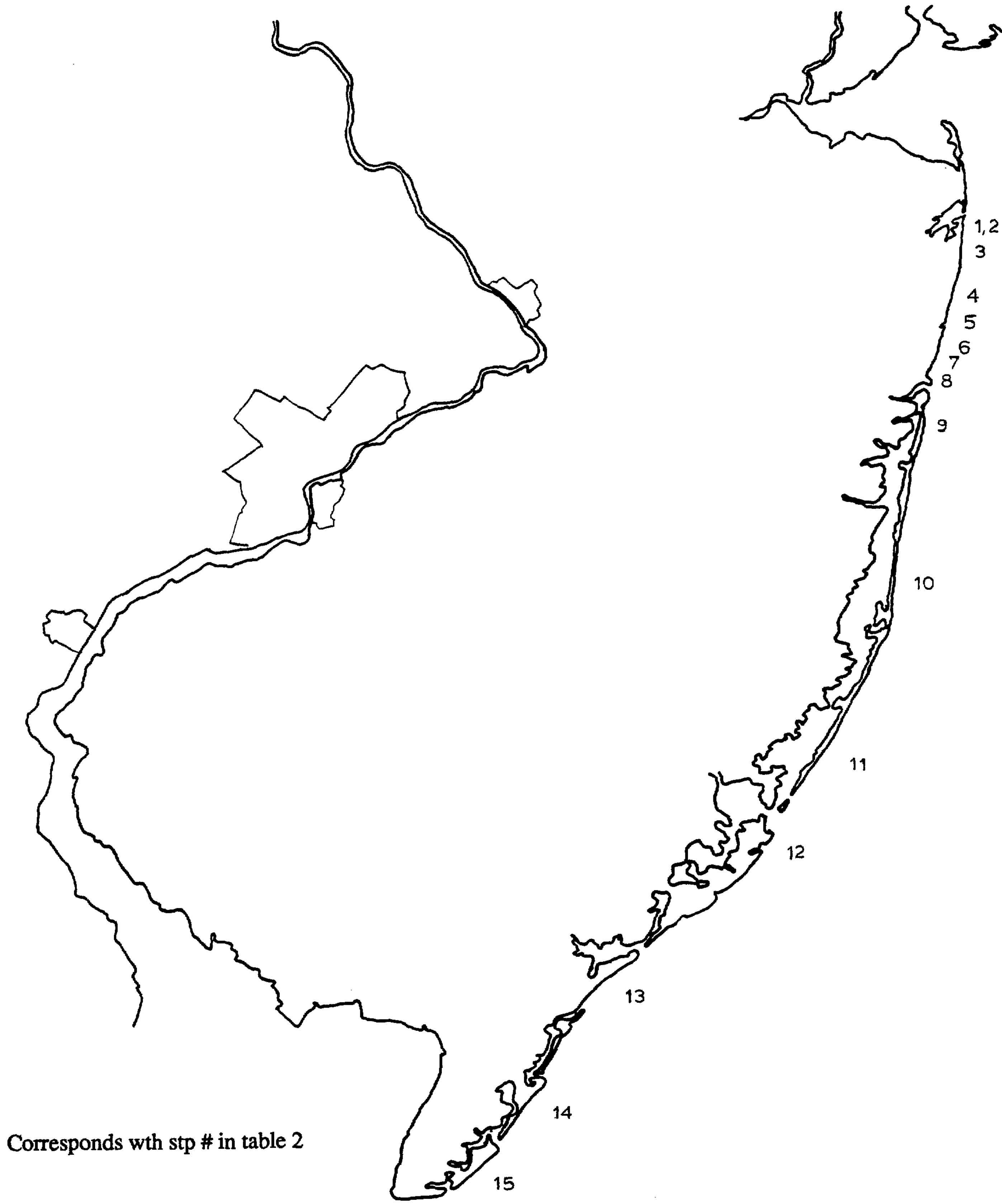


Figure 20. Major STPs with Ocean Outfalls in the New Jersey Atlantic Coastal Drainage (Cahill and Associates from NJDOH, 1988)

TABLE 3.

SUMMARY OF SEWAGE TREATMENT PLANT DISCHARGES TO THE ATLANTIC COASTAL DRAINAGE SANDY HOOK TO CAPE MAY

(PLANTS WITH OCEAN OUTFALLS ONLY)

(Derived from NOAA, 1986)

COASTAL COUNTY	NO. OF STP's	FLOW (MGY x 100)	MASS DISCHARGE (Tons per year) BOD5	TN	TP
MONMOUTH	8 major	137.5	15.8	6.5	4.0
	2 minor	3.4	2.3	0.2	0.2
OCEAN	4 major	68.5	3.9	3.3	2.0
	1 minor	0.4	0.3	0.0	0.0
ATLANTIC	1 major	67.1	4.5	3.1	2.0
CAPE MAY	3 major	38.1	7.0	1.7	1.1
	2 minor	3.8	2.5	0.2	0.2
TOTALS	21	318.3	36.3	15.1	9.5

Note: If the total number of sewage treatment plants (83) in these counties is included, the total flow is 394.5 x100 million gallons per year (MGY). Thus, these ocean outfalls comprise 81% of total wastewater production in the four counties shown. This data is somewhat different from Table 2 because of the date of source information.

nutrient enrichment of coastal waters, in that the original sources of both are probably the same--anthropogenic activity. There are apparent contradictions to this conclusion, in that sampling in Bight waters during 1986 (EPA, 1987) showed low bacterial levels where significant algae blooms occurred. These two pollutant phenomena, however, do not necessarily occur simultaneously in the same aquatic environment. That is, the various wastewater discharges which convey bacteria and nutrients into coastal waters can produce immediate bacteriological impacts and long term algae stimulation in the same waters. Bacteria which are flushed from the land surface with rainfall may cause sudden and dramatic increases in FC concentrations, while the nutrients which are transported with the same runoff will help to cause an algae bloom several hours, days, or even weeks later, depending on the occurrence of other natural conditions. For the nutrients, the transformation from runoff-transported pollutant to algae food source probably involves one or more biochemical changes before entering the nearshore coastal waters, whereas the microbial indicators are probably the result of direct discharges of decomposing organic matter, be it human or animal feces, detritus, or some type of decomposing terrestrial or aquatic vegetation.

This then raises the question of the role played by the estuary waters in receiving inland and direct shoreline runoff and processing/transforming these waters before discharging into the coastal environment. Should lakes and rivers in the Atlantic coastal drainage and the seven inlets from Barnegat to Herford (Figure 21) be considered to be major sources of bacterial and nutrient contamination to the nearshore ocean zone, directly and indirectly impacting bathing waters? Unfortunately, the answer to this question is a qualified "yes," although the distinction between impacts from stormwaters which drain directly from the barrier islands versus the indirect impacts of enriched waters flowing from the back bays has yet to be made.

Other Pollutants: The omission of a discussion of other pollutants in this chapter is not an indication of their relative unimportance in coastal waters, but rather reflects the inadequacy of the data base. We know that land runoff produces significant amounts of organic pollutants, as measured by parameters such as chemical oxygen demand (COD), petroleum hydrocarbons, heavy metals and a broad spectrum of synthetic organics. The sampling record for the concentration of these parameters in coastal waters, however, is virtually nonexistent. Nevertheless, sufficient knowledge exists from other studies to assume that coastal stormwater drainage contains these pollutants, and that they must be included in any water quality management strategy.

Estimates of Nonpoint Source Pollutant Loadings: Several investigators have attempted to estimate the total input of major pollutant forms into the New Jersey ocean waters. From a rigorous scientific perspective, all such estimates should be considered preliminary at best. In 1976 the National Oceanic and Atmospheric Administration (NOAA), Environmental Research Laboratories, conducted a series of studies on pollutant inputs to the New York Bight ("Contaminant Inputs to the New York Bight," Mueller et al, 1976). This report developed estimates of point source loadings for New Jersey ocean waters, including both municipal and industrial wastewaters, as well as an estimate of land runoff pollutants (Table 4). This data was developed by using the available USGS gaged runoff data and applied over the total (gaged and ungaged) drainage area, estimated to be approximately 2,000 square miles. Mueller developed weighted average concentrations of pollutants as shown in Table 4, but other studies have shown that greater weight should be given to certain pollutants which dramatically increase in absolute concentration during runoff, such as COD and total phosphorus. Also, the sampling stations which generated this water chemistry record (Figure 22) were all situated well inland within the Atlantic coastal drainage area, and the data analyzed was for the period prior to 1974 . Of special

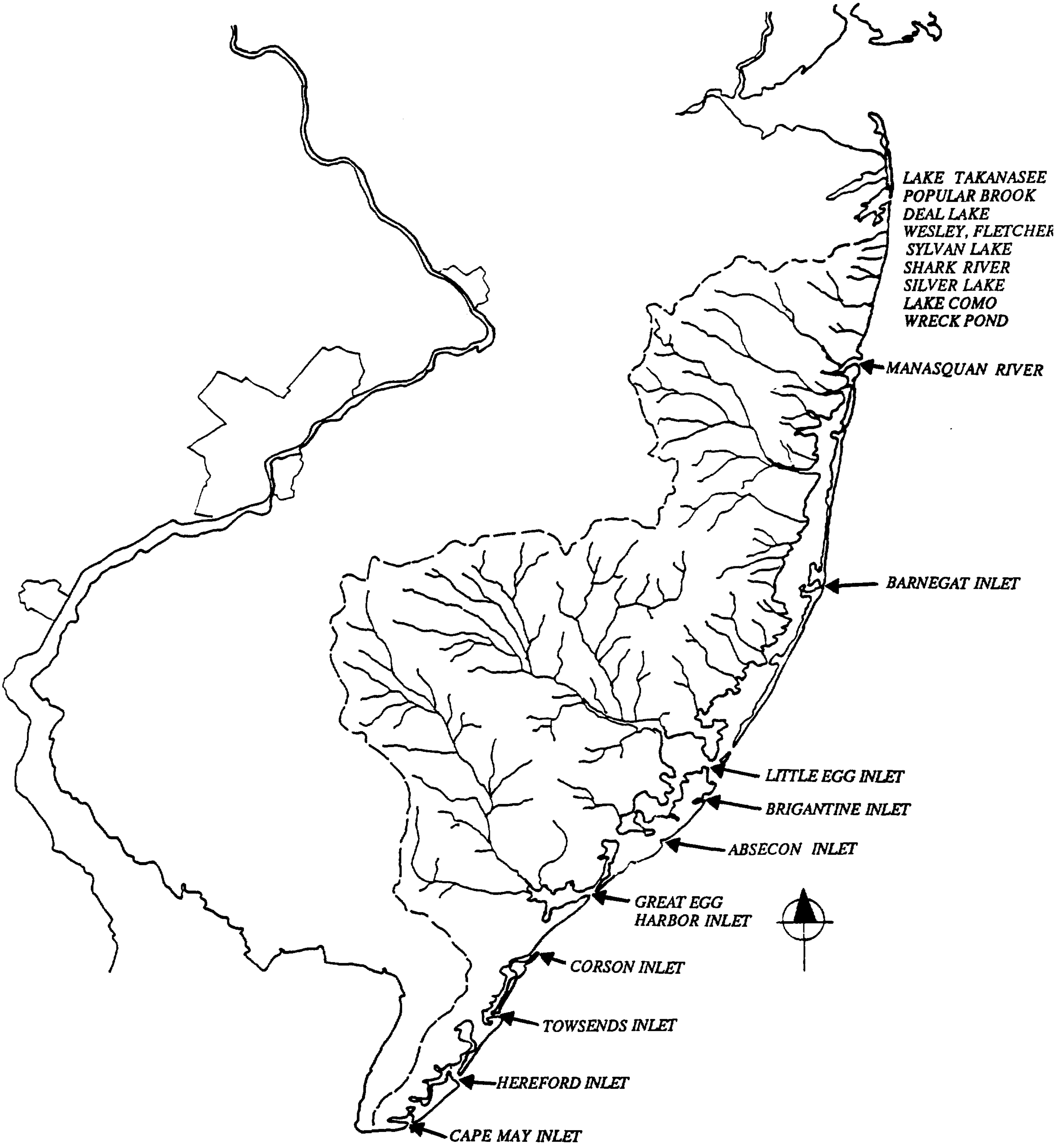


Figure 21. Discharges from Bays and Rivers along the Coastal Zone (Cahill and Associates from NJDOH, 1988)

TABLE 4.

NOAA Estimates of Land Runoff in New Jersey Atlantic Coastal Drainage (Mueller, et al, 1976)

Parameter	Gaged Runoff weighted avg. conc., mg/1	Total Runoff mass load metric tons/day
Drainage Area, mi^2	727	2,000
FLOW, cfs	1200[a]	3,300
cfs/mi^2	1.65	
ss	9.8	79
ALK	5.8	47
BOD_5	1.5	12
COD[b]	5.5 x BOD_5	66 (1)
TOC	8.9	72
MBAS	0.014	0.11
O&G	8.5	69
NH_3-N	0.20	1.6
ORG-N	0.25	2.0
TKN	0.45	3.6
NO_2+NO_3-N	1.6	12.9
TOTAL-N	2.05	16.5
ORTHO-P	0.78 Tot.P	0.58
TOTAL-P	0.092	0.74 (1)
Cd	0.001	0.0081
Cr	0.00079	0.0064
Cu	0.0080	0.065
Fe	0.64	5.2
Hg	Nil	Nil
Pb	0.0015	0.012
Zn	0.032	0.26
F.Coli[c]	59	480
T.Coli[c]	6.9 F.Coli	3,300

a. Average flow for period of record; average survey flow = 1,650 cfs.

b. From Transect Zone gaged runoff.

c. Coliform geometric mean load; concentration [=] org/100ml,
load [=]10^{10} org/day.

(1) Nature of sampling record probably underestimates the mass load of certain pollutants whose concentration increases significantly during stormwater runoff, such as COD and TP. (Cahill and Associates, 1988)

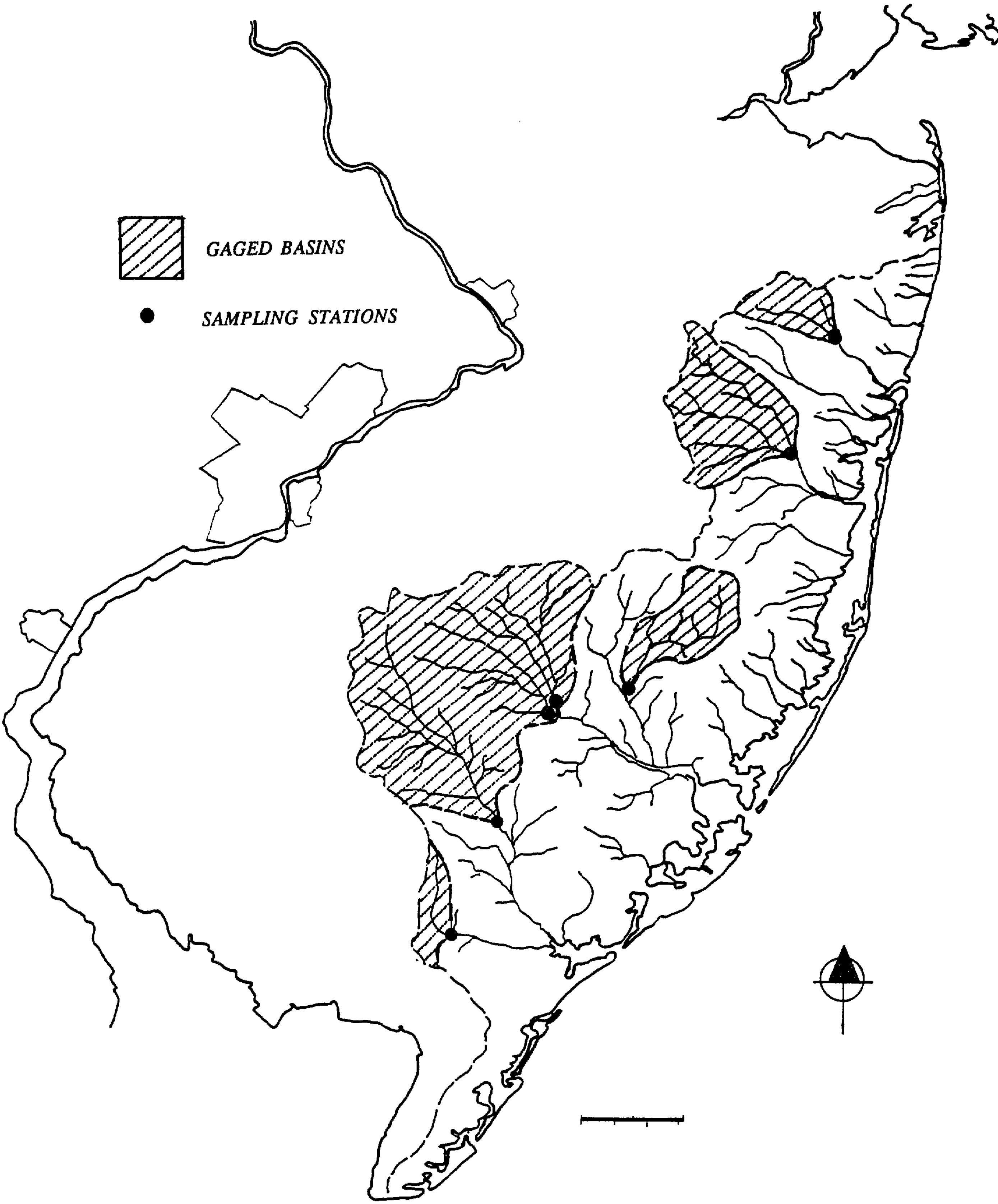


Figure 22. Gaged Drainage Areas In the New Jersey Atlantic Coastal Drainage (Cahill and Associates from Mueller et al, 1976)

interest are the ambient concentrations for total phosphorus (0.092 mg/l) and total nitrogen (2.05 mg/l) used in this analysis.

Although the basic pollutant transport processes of nonpoint pollutants are the same, the scales of these processes can be vastly different in different parts of the Atlantic coastal drainage system. At one extreme is the apex area of the New York Bight (northwestern corner of the coastal region), where water quality is dominated by the diverse pollution sources in the Hudson-Raritan complex of discharges. This water quality context is such a unique situation that it bears little comparison to ocean, back bay, and the other waters within Atlantic coastal drainage. When considered in the context of the much larger problem of contaminant inputs to the Bight, the nonpoint source coastal zone input was estimated by NOAA to be relatively minor, and the numerous primary treatment STP's were recognized as a more significant problem (more than 85% of the municipal wastewater discharge at that time). The loads from the New York metropolitan area, of course, dwarfed the New Jersey loadings. Nevertheless, the total annual input to Bight waters from land runoff was estimated to be 0.74 metric tons per day or 270 metric tons (298 tons) per year of total phosphorus (Table 5). For total nitrogen, the runoff input was estimated to be 16.5 metric tons per day or 6,022 metric tons (6,640 tons) per year. The corresponding population statistic for the relevant Bight drainage area was an estimated 875,200 people, as based on the 1970 Census. The point source load estimate (not shown in Table 5) was 2.4 times greater for total phosphorus and about one half of the nonpoint source loading for total nitrogen.

An update of this study in 1982 focused on the impacts of the New York metropolitan region and the tributary inputs from the major river systems flowing into the Bight, but did not update the New Jersey nonpoint source estimates. In 1987, other investigators (Lee and Jones, 1987) evaluated the water quality benefits of nutrient reduction, specifically phosphorus, from point sources in the Bight. The argument was developed that "... 75% of the summer, land based phosphorus load to northern New Jersey coastal waters is from coastal domestic wastewater discharges." This analysis of pollutant loadings includes an estimate of New Jersey nonpoint source phosphorus based on the statistic of 0.05 grams per square meter per year. Assuming a uniform contribution from the 2,000 square mile drainage area, a total of 259,000 kilograms per year (erroneously reported as 500,000 kilograms per year) was estimated. This is equal to 259 metric tons per year or 0.71 metric tons per day (very close to the Mueller statistic), or 285 tons per year. For total nitrogen, this study estimated an NPS loading of 5,000 metric tons per year, or 5,507 tons per year, again very close to the NOAA estimates.

The unit area statistics used in these two estimates are interesting when compared to a variety of data developed in watersheds from across the country in different watersheds (Table 6). The database for the New Jersey Atlantic coastal drainage is somewhat inferior to many databases in other drainage basins, because it only samples a portion of the inland drainage (Figure 22), and because it fails to frequently measure the whole spectrum of nonpoint source pollutants. By comparison, researchers in other watersheds elsewhere in the country (e.g., the Honey Creek basin in north central Ohio and other similar watersheds in the Great Lakes and Lake Erie region; Baker, 1985) have developed sufficient data to reach conclusions concerning the importance of nonpoint source pollution. In the Honey Creek basin (287 square miles), 4,500 chemical samples were analyzed during both storm runoff and dry conditions during a 10-year period, and offer the kind of data base on which decisions can be made with some degree of confidence. Similar sampling programs must be designed and conducted within New Jersey's Atlantic coastal drainage and beyond. Only by conducting such an integrated flow and storm sampling record can we accurately estimate the mass transport of nonpoint source pollutants throughout Atlantic coastal drainage--from headwaters to back bays and estuaries to ocean waters themselves.

TABLE 5.

POLLUTANT LOADING ESTIMATES
NEW JERSEY COASTAL ZONE

(Assumed drainage area = 2,000 sq mi or 5,180 sq km)

	YEAR	DRAINAGE AREA (sq mi)	ANNUAL INPUT (tons/year) NO3-N	TN	TP	BOD5	SS	Q(mgy) x10^5
NONPOINT SOURCES								
Mueller et al (1)	1976	2,000	5,191	6,640	298	4,828	31,790	7.84 (3)
Lee and Jones	1987			5,510	285			
NJDEP (2)	1988		1,150		101		82,250	

POINT SOURCES

	YEAR	Number of STPs (with ocean outfalls)	TN	TP	BOD5	SS	Q(mgy)
NOAA	1986	21	1,510	950	3,630		0.32
Lee and Jones	1987		2,204	1,322			

(1) Based on weighted average concentration of gaged runoff
(2) Summarized in "Governor's 14-Point Action Plan," 1988
(3) Assumed 22.5 inches of runoff per year

TABLE 6.

COMPARISON OF UNIT AREA LOADINGS
(kilograms/hectare/year)

	Total Nitrogen	Total Phosphorus
Mueller et al (1977)	11.6	0.52
Lee and Jones (1987)	9.6	0.50
Baker et al (1987)	21.0	1.32 (Agricultural basin)
Baker et al (1987)	11.0	0.55 (Non-agricultural basin)
NURP, EPA (1983)	1.8 - 16.6	0.22 - 2.15 (Urban watersheds)

One other recent estimate of land runoff to the coastal waters was developed in a New Jersey policy paper; however, we have not been able to confirm the source of this information from within NJDEP or any other State agency. These numbers are included in Table 5 for comparison purposes only. Based on our review of the partial information available for the Atlantic coastal drainage itself together with studies from other watersheds, these statistics appear to significantly underestimate stormwater loadings.

Significance of Point Sources

The relative significance of wastewater treatment facilities in the coastal region and their relationship to the issue of nonpoint sources is complex. On one hand, nonpoint issues emerge as relatively more important as municipal and industrial point source discharges are upgraded and outfalls relocated farther out in ocean waters.

> "Central Ocean County presents a vivid example. Ocean County developed an extensive regional sewage system that eliminated numerous small, older facilities in the late 1970's. As a result, Barnegat Bay water quality conditions improved in many sections to the point where shellfish harvesting resumed. But, recent water quality data show a reverse trend due to increased run-off and other non-point sources. The sewage facilities that were once expected to bring significant improvements in water quality are now making possible large scale development on lands adjacent to to the bay's waterfront. The resulting population increase--more than 80 percent in certain municipalities since 1970--has created a new burden of non-point pollution sources for the area. Controlling this pollution will be a major water quality issue for the coming decade."
>
> ("New Jersey's Environment," NJDEP, 1988)

The upgrading of treatment facilities in the coastal region is considered a significant step forward in improving coastal water quality, and the State points to the comparison between 1976, when 141 MGD of primary and inadequately treated wastewaters were discharged and 1988, when 100% advanced secondary treatment was provided by coastal STP's. At the same time, if nitrogen and phosphorus are the nutrients which drive the excessive algal growth in the near shore waters, then the net loading has actually increased during this period. Table 5 clearly illustrates that the point source input from STP's, even modern secondary facilities which do an excellent job of reducing organics and solids, still represent the single greatest source of total phosphorus to coastal waters, albeit near shore rather than embayment.

> **Based on review of available data from the various Federal, State, and local reports available, it is difficult to make overall judgments about the quality of water and water quality trends in the Atlantic coastal drainage. Point source sewage treatment plants which discharge directly into ocean waters have been upgraded considerably within the last several years, with the construction of several new regional secondary sewage treatment plants, and sewage effluent outfalls have been extended farther out into the ocean. Nevertheless, while this new construction has dramatically reduced certain types of wastewater pollutant loadings such as fecal coliform bacteria, biochemical oxygen demand and suspended solids, certain pollutants such as the nutrients phosphorus and nitrogen have basically gone unaffected. As a matter of fact, nutrient loadings from these larger regional plants, accommodating ever-increasing amounts of land**

development activity, actually are increasing, as these new plants have been constructed without nutrient removal of any sort.

Furthermore, there seems to be little doubt that nonpoint source water quality loadings of various sorts are increasing. These increased loadings are reflected in several parameters such as fecal coliform, nitrogen and phosphorus. Toxics, including hydrocarbons, heavy metals, pesticides and herbicides, volatile organics, and other pollutants also make their way into Atlantic coastal drainage waters with serious impacts, but are largely unmeasured at present.

We conclude that a much more comprehensive water quality monitoring and sampling program must be formulated and implemented as quickly as possible within the Atlantic coastal drainage (and elsewhere) so that the State can gauge the true seriousness of the stormwater quality problem, its causes and effects, and the degree to which our management programs are successful.

CHAPTER 2.

GROWTH AND REGULATION IN THE COASTAL ZONE

CHAPTER 2.

NEW JERSEY'S EXISTING REGULATIONS WITHIN COASTAL WATERS AND THEIR EFFECT ON FUTURE GROWH

The Regulated Coastal Zone: CAFRA, Waterfront Development, Coastal Wetlands Permits

The preceding sections describe a region which, from a hydrologic perspective, establishes the framework for understanding and analyzing the water resources of New Jersey's coastal waters. During the past 15 years, the State has formulated a regulatory system for the coastal zone. This existing State system establishes a much narrower set of boundaries than hydrology would prescribe. A mix of technical and political decisions in the early 1970's led to the definition of a regulated coastal zone under the jurisdiction of New Jersey's Coastal Area Facilities Review Act (CAFRA), enacted in 1973, in combination with the State's Waterfront Development Act and the 1970 coastal wetlands permit regulations (Kinsey 1986). From a regulatory perspective, these three different laws, regulating certain types of new development under certain conditions, establish what we will refer here to as the current regulated coastal zone (Figure 23; the zone also includes all other areas now or formerly flowed by the tides as well as the Hacksensack Meadowlands District). The limits of this zone when superimposed onto Atlantic coastal drainage as defined in the first section of this Manual equates to about an 800 square mile area from Sandy Hook to Cape May. From a nonpoint source water quality perspective, then, it is important to keep in mind that the area regulated by the State's coastal program at the present time comprises only a portion (40%) of the total Atlantic coastal drainage area (Figure 3).

As stated, the objective of this Manual is to develop and propose additional water quality measures and techniques--best management practices or BMP's--which can be integrated into the coastal permitting system at NJDEP's Division of Coastal Resources. The first step in the analytical process is to understand and address the water quality context and the relationship of the coastal permitting program to water quality, as set out in the preceding sections. Although certainly not all of the cause and effect questions surrounding water quality problems in New Jersey coastal waters have been answered, at least a general understanding of the various sources of pollution and how they act to degrade coastal waters has been developed here. Having established this water quality understanding, the existing array of regulations which directly and indirectly affect water quality now must be evaluated, so that existing water quality problems can be overlaid onto existing regulations in an attempt to make statements about the adequacy of the existing regulatory program--what regulations exist, what regulations need to be enforced more rigorously, what need to be expanded, and so forth. Therefore, some comments about the existing regulatory program are in order.

1. Within the geographical jurisdiction of the coastal permitting program, permits, of course, are not required for existing sources of nonpoint source pollution (i.e., any sort of existing development). We have not been able to locate statistics on existing land use within Atlantic coastal drainage and/or the currently regulated subset of that zone. As a proxy, Tables 7 through 14 indicate that there were 192,375 persons in the Atlantic County portion of the coastal drainage area in 1980 (probably well over 200,000 persons at the

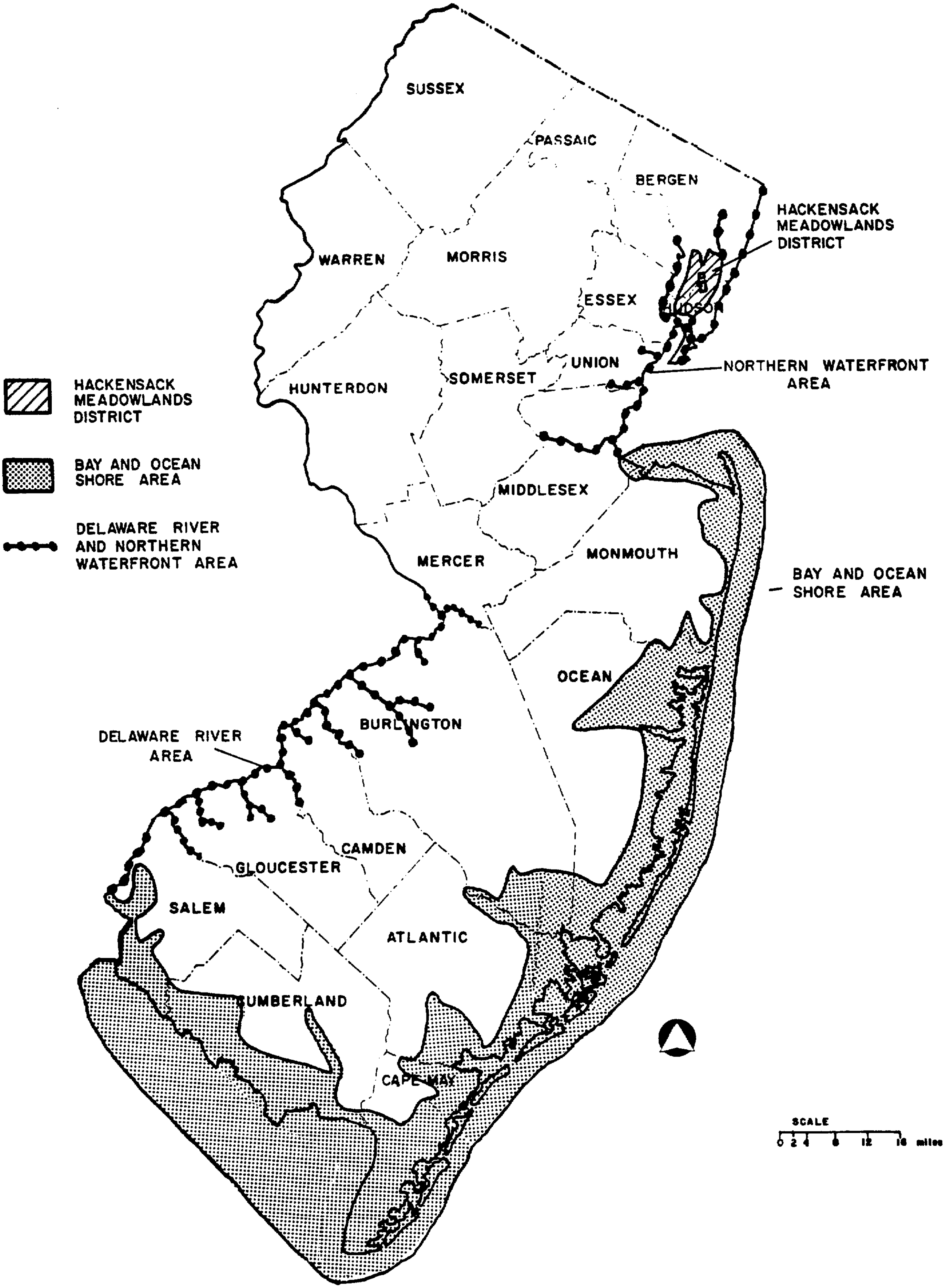


Figure 23. New Jersey Coastal Areas Regulated by NJDEP's Division of Coastal Resources (NJDEP, 1986)

Table 7. Population and Housing Data for Atlantic County within CAFRA Zone (Cahill and Associates, 1988)

	Population	Dwelling Units (2)			CAFRA (3)	Population Projections (4)	
	1980	1985	1986	1987	Permits	1995	2005
Absecon	6,859	32	73	39	203 rms	8,233	9,061
Atlantic City	40,199	1,018	93	203	484 DU's; 2222 rms	46,721	53,189
Brigantine	8,318	365	412	309	474 rms	879	12,452
Corbin City	252		3	3		285	305
Egg Harbor City (1)	4,618	10	4	4	172 DU's	5,446	5,946
Egg Harbor Twp. (1)	19,381	282	238	173	861 rms	29,135	35,021
Galloway (1)	12,176	303	645	350	24 rms; 1 retail	21,854	27,740
Linwood	6,144	30	34	92	208 DU's	6,638	6,936
Longport	1,249	14	20	28		1,404	1,498
Margate	9,179	40	98	50		10,436	11,194
Northfield	7,795	17	28	27	120 DU's	8,075	8,243
Pleasantville	13,435	372	216	249	675 DU's	16,509	18,665
Port Republic	913	12	11	13		1,290	1,516
Somers Point	10,330	100	44	173	183 rms	12,534	13,864
Ventnor	11,704	19	36	103		12,812	13,480
	134,465	2,317	1,512	1,553	1,573 DU's; 3,524 rms	154,034	184,757

(1) Only 50% of number listed here is included in total due to the fact that only a portion of the municipality is contained within CAFRA zone.
(2) Based on NJDOL Residential Building Permits Annual Summaries.
(3) NJDEP CAFRA permit for 1985-7.
(4) NJDOT 1988.

Table 8. Population and Housing Data for Atlantic County outside CAFRA Zone (Cahill and Associates, 1988)

	Population		Dwelling Units (2)		CAFRA (3)	Population Projections (4)	
	1980	1985	1986	1987	Permits	1995	2005
Buena (1)	3,642	11	16	13	0	3,940	4,268
Buena Vista	6,959	15	27	32	0	9,002	10,234
Egg Harbor City (1)	4,618	10	4	4	172	5,446	5,946
Egg Harbor Twp. (1)	19,381	286	238	173	0	29,135	35,021
Folsom	1,892	6	3	4	0	2,109	2,239
Galloway (1)	12,176	303	645	350	0	21,854	27,740
Hamilton	9,499	344	259	455	0	19,253	25,139
Hammonton	12,298	37	82	97	0	13,621	14,419
Mullica	5,243	18	55	37	0	6,559	7,353
Weymouth	1,260	61	34	5	0	1,856	2,214
Estell Manor	850	19	22	24	0	1,323	1,609
	57,910	805	934	924	86	83,911	99,695

(1) Only 50% of number listed here is included in total due to the fact that only a portion of the municipality is contained within Atlantic drainage.
(2) Based on NJDOL Residential Building Permits Annual Summaries.
(3) NJDEP CAFRA permit file 1985-7.
(4) NJDOT 1988.

Data Summary: CAFRA units totalled 1,659 out of a total of 8,045 dwelling units permitted (20.6%). Within the CAFRA zone, CAFRA permits were 1,573 (29.2%) out of 5,382 total permits issued. Total population of Atlantic County in 1980 was 192,375 which was projected to increase to 237,945 by 1995 (increase of 23.7%).

Table 9. Population and Housing Data for Monmouth County within CAFRA Zone (Cahill and Associates, 1988)

	Population 1980	Population 1987	Dwelling Units (2) 1985	1986	1987	CAFRA (3) Permits	Population Projections (4) 1995
Allenhurst	912	925	30	0	0	0	944
Asbury Park	17,015	16,836	0	31	13	0	16,940
Atlantic Highlands (1)	4,950	5,050	9	9	62	0	5,211
Avon-by-the-Sea	2,337	2,329	0	0	0	0	2,332
Belmar	6,771	6,840	8	11	8	0	6,970
Bradley Beach	4,772	4,812	19	2	44	0	5,169
Brielle	4,068	4,762	75	18	11	0	5,279
Deal	1,952	2,004	3	1	4	0	2,079
Fair Haven	5,679	5,791	13	4	50	57 DU's	6,023
Hazlet (1)	23,013	24,114	58	12	54	12 DU's	24,975
Highlands	5,187	5,568	1	37	24	0	6,153
Interlaken	1,037	1,037	0	0	0	0	1,037
Keansburg	10,613	10,753	18	70	79	35 DU's	11,074
Keyport	7,413	7,549	17	33	142	90 DU's	8,087
Little Silver	5,548	5,700	48	45	54	0	302
Loch Arbour	369	372	0	0	0	0	378
Long Branch	29,819	31,099	120	134	63	123 DU's; 450 rms	32,631
Manasquan	5,354	5,617	14	49	25	0	5,883
Monmouth Beach	3,318	3,744	17	24	20	0	3,858
Neptune City	5,276	5,539	2	7	6	0	5,711
Oceanport	5,888	6,481	53	31	28	Offices	6,982
Red Bank (1)	12,031	12,211	0	73	46	0	12,764
Rumson	7,623	7,745	16	15	13	0	7,849
Sea Bright	1,812	1,974	2	16	0	0	2,110
Sea Girt	2,650	2,722	11	6	3	0	2,813
Shrewsbury Bor.	2,962	3,050	0	38	64	133 DU's	3,556
South Belmar	1,566	1,583	1	51	7	0	1,705
Spring Lake	4,215	4,260	6	6	8	0	4,369
Union Beach	6,354	6,573	24	15	19	0	6,896
West Long Branch	7,380	8,057	59	22	23	0	8,381
Total	177,887	184,410	591	713	789	444 DU's; 450 rms	186,986

(1) Only 50% of number listed here is included in total due to the fact that only a portion of the municipality is contained within CAFRA Zone.
(2) Based on NJDOL Residential Building Permits Annual Summaries.
(3) NJDEP CAFRA permit for 1985-7.
(4) Monmouth County, 1988.

Table 10. Population and Housing Data for Monmouth County outside CAFRA Zone (Cahill and Associates, 1988)

	Population	Population	Dwelling Units			CAFRA	Population Projection
	1980	1987	1985	1986	1987	Permits	1995
Aberdeen Twp.	17,235	18,467	30	129	110	147 DU's	20,035
Atlantic Highlands (1)	4,950	5,050	9	9	62	0	5,211
Colts Neck	7,888	8,707	52	81	72	0	9,592
Eatontown	12,703	14,528	255	39	43	0	15,476
Farmingdale	1,348	1,433	0	9	20	0	1,719
Freehold Bo.	10,020	10,630	29	221	15	0	11,174
Freehold Twp.	19,202	23,104	389	661	501	0	35,288
Hazlet (1)	23,013	24,114	58	12	54	12 DU's	24,975
Holmdel	8,447	11,893	330	197	81	44 DU's	18,648
Howell	25,065	37,315	1,633	1,345	339	0	51,604
Marlboro (1)	17,560	26,904	483	684	337	0	36,844
Matawan	8,837	8,985	11	36	64	0	9,475
Middletown	62,574	70,109	435	241	210	0	72,288
Millstone (1)	3,926	4,798	87	109	46	0	7,327
Neptune	28,366	29,387	130	112	80	0	31,335
Ocean	23,570	24,909	140	281	219	0	28,000
Red Bank (1)	12,031	12,211	0	73	96	0	12,764
Shrewsbury Twp.	995	1,141	50	0	0	0	1,220
Spring Lake Heights	5,424	5,890	18	17	13	0	6,059
Tinton Falls	7,740	6,573	368	373	722	0	16,497
Wall	18,952	21,014	167	128	119	0	28,767
	289,106	330,624	4,356	4,314	2,945	197 DU's	389,128

(1) Only 50% of number listed here is included in total due to the fact that only a portion of the municipality is contained within CAFRA Zone.
(2) Based on NJDOL Residential Building Permits Annual Summaries.
(3) NJDEP CAFRA permit for 1985-7.
(4) Monmouth County, 1988.

Data Summary: CAFRA units totalled 641 in both zones, out of a total of 13,665 units permitted (4.7%). Within the CAFRA zone, CAFRA permits included 21.2% of total permits issued, whereas in the drainage outside of CAFRA, CAFRA permits included only 1.7% of total permits issued. Total 1980 population of the entire zone was 466,933 which had increased to 515,037 by 1987 with the 1995 projection at 593,773, another 78,736). Rates of growth within the CAFRA zone are much smaller (15,149, 1980-1995) than for the non-CAFRA portion of the drainage (111,631, 1980-1995) which is a problem, given that so little of this new development appears to be CAFRA controlled/affected.

Table 11. Population and Housing Data for Ocean County within CAFRA Zone (Cahill and Associates, 1988)

	Population 1980	Population 1986	Dwelling Units (2) 1985	Dwelling Units (2) 1986	Dwelling Units (2) 1987	CAFRA Permits (3)	Population Projection 2000 (4)
Barnegat (1)	8,702	10,576	136	328	361	182 DU's	18,000
Barneget Light	619	749	31	33	25	0	1,000
Bay Head	1,340	1,381	3	5	5	0	1,800
Beach Haven	1,714	2,032	24	26	35	0	2,600
Beachwood	7,687	8,657	135	129	66	0	9,000
Berkeley (1)	23,151	35,278	1,342	1,000	1,113	642 DU's	48,000
Brick	53,629	65,077	1,020	941	694	763 DU's	75,000
Dover	64,455	74,688	791	1,287	1,777	2466 DU's; 459 rms.	85,000
Eagleswood	1,009	1,127	11	13	12	0	3,000
Harvey Cedars	363	391	17	15	36	0	550
Island Heights	1,575	1,676	9	6	29	0	1,900
Lacey (1)	14,161	19,762	796	431	341	181 DU's	25,000
Lakewood	38,464	41,043	81	566	3,515	1149 DU's; 100 rms.	53,500
Lavallette	2,072	2,238	92	15	21	0	2,700
L. Egg Harbor	8,483	12,018	220	633	1,720	0	16,100
Long Beach	3,488	3,831	169	146	120	0	7,000
Mantoloking	433	452	3	3	3	0	550
Ocean (1)	3,731	4,325	104	91	106	98 DU's	10,800
Ocean Gate	1,385	1,523	14	15	12	0	1,700
Pine Beach	1,796	1,850	7	9	11	0	2,400
Pt. Pleasant Bor.	17,747	19,254	162	137	82	0	22,000
Pt. Pleasant Beach	5,415	5,678	43	30	34	0	6,800
Seaside Heights	1,802	2,003	49	61	53	57 rms	2,100
Seaside Park	1,795	2,021	15	137	27	0	2,700
Ship Bottom	1,427	1,814	17	129	24	0	2,200
S. Toms River	3,954	3,975	0	5	8	0	4,000
Stafford (1)	10,385	13,162	250	275	183	139 DU's	30,000
Surf City	1,571	1,649	20	16	29	0	1,900
Tuckerton	2,472	2,625	7	24	95	140 DU's	3,500
	250,519	293,295	4,144	5,127	8,625	5,139 DU's; 616 rms.	366,850

(1) Only 50% of number listed here is included in total due to the fact that only a portion of the municipality is contained within CAFRA Zone.
(2) Based on NJDOL Residential Building Permits Annual Summaries.
(3) NJDEP CAFRA permit for 1985-7.
(4) Ocean County Planning Board 1988.

Table 12. Population and Housing Data for Ocean County outside CAFRA Zone (Cahill and Associates, 1988)

	Population 1980	Population 1986	Dwelling Units (2) 1985	Dwelling Units (2) 1986	Dwelling Units (2) 1987	CAFRA Permits (3)	Population Projection 2000 (4)
Barnegat (1)	8,702	10,576	136	328	361	182 DU's	18,000
Berkeley (1)	23,151	35,278	1,342	1,000	1,113	642 DU's	48,000
Jackson	25,644	31,585	536	1,039	528	0	51,000
Lacey (1)	14,161	19,762	796	431	341	181 DU's	25,000
Lakehurst	2,908	2,923	1	2	9	0	3,600
L. Egg Harbor (1)	8,483	12,018	220	633	1,720	0	16,100
Manchester	27,987	33,773	621	853	690	92 DU's	53,000
Ocean (1)	3,731	4,325	104	91	106	98 DU's	10,800
Stafford (1)	10,385	13,162	250	275	183	139 DU's	30,000
Totals	90,846	115,842	2,582	3,273	3,139	713 DU's	181,550

(1) Only 50% of number listed here is included in total due to the fact that only a portion of the municipality is contained within CAFRA Zone.
(2) Based on NJDOL Residential Building Permits Annual Summaries.
(3) NJDEP CAFRA permit for 1985-7.
(4) NJDOT 1988.

Data Summary: Total CAFRA approvals were 5,909 out of 26,890 permits issued or 22.0% within total drainage. Most of the building occurred within CAFRA portion (66.5%). Within this area CAFRA covers 29.0% of total only. Total population of this area was 341,363 (1980) which had increased to 409,133 by 1986. Significant growth occurred both within and without CAFRA jurisdiction within this drainage. The total area is projected to grow to 548,400 by 2000 - a tremendous growth rate, with 65,709 of that being ouside of CAFRA and 73,558 within CAFRA (i.e., growth is, relatively speaking, radiating outward from the coast, occurring more outside of CAFRA area, although large amounts of growth are still expected within CAFRA). Projections are based on Ocean County Planning Board area work. Also, note that we have adjusted for large developments in Dover, Lakewood, L. Egg Harbor, where we know that NJDOL figures have not already included them.

Table 13. Population and Housing Data for Burlington County within CAFRA Zone (Cahill and Associates, 1988)

	Population 1980	Population 1987	Dwelling Units (2) 1985	1986	1987	CAFRA (3) Permits	Population Projection (4) 2010
Bass River (1)	1,344	1,437	5	3	7	0	1,910
Washington (1)	807	807	5	1	1	0	1,220
Total	874	920	4	2	4	0	1,260

(1) Only 50% of Bass River and 75% of Washington figures given here have been included in totals due to the fact that only portions of these municipalities are contained within CAFRA Zone.
(2) Based on NJDOL Residential Building Permits Annual Summaries.
(3) NJDEP CAFRA permit for 1985-7.
(4) NJDOT 1988.

Table 14. Population and Housing Data for Burlington County outside CAFRA Zone (Cahill and Associates, 1988)

	Population 1980	Population 1987	Dwelling Units (2) 1985	1986	1987	CAFRA Permits (3)	Population Projections 2010 (4)
Bass River (1)	1,344	1,437	5	3	7	0	1,910
Shamong	4,537	5,229	96	49	53	0	7,210
Tabernacle	6,236	7,229	32	45	76	0	9,660
Washington (1)	808	807	5	1	1	0	1,220
Woodland (1)	2,285	2,083	3	16	9	0	2,620
Total	13,765	15,344	137	108	140	0	20,705

(1) Only 50% of Bass River and 75% of Washington and Woodland figures given here have been included in total due to the fact that only portions of these municipalities are within Atlantic coastal drainage.
(2) Based on NJDOL Residential Building Permits Annual Summaries.
(3) NJDEP CAFRA permit for 1985-7.
(4) Burlington County Planning Board, 1988, as based on Delaware Valley Regional Planning Commission projections.

Data Summary: No CAFRA permits were approved at all in Burlington vs. 10 units shown within CAFRA zone and 384 outside of CAFRA but within drainage (total of 394). Population (1980) has increased from 14,639 to 16,264, a modest increase of 1,625 by 1987 and is projected to increase to 21,965 by 2010, or another 5,701 persons.

present time), 515,034 persons in the Monmouth County portion (1987), 409,137 persons in the Ocean County portion (1986), 16,264 persons in the Burlington County portion, not to mention the additional portions within Cape May, Cumberland, Camden, and Gloucester County areas (these county portions comprised 166, 49, 93, and 59 square miles of direct drainage respectively, according to Mueller, 1977). In other words, developed land uses are vast and are comparable to those normally associated with upwards of 1.5 million persons in the Atlantic coastal drainage area. Additionally, there is a tremendous amount of land use activity oriented toward tourism and seasonal use here, with a summer influx of several hundred thousand transient residents.

> **The point that we want to stress here is that although there are techniques and practices available to reduce these nonpoint sources by retrofitting existing stormwater conveyance systems, the coastal permitting program as it currently is structured does not--cannot--affect existing nonpoint sources in any way. Coastal permitting only regulates new development. Although current estimates of existing nonpoint loadings in the Atlantic coastal drainage have not been calculated with any precision, these loadings are significant. Therefore, nonpoint source loadings from existing land uses is an important issue, and management of this nonpoint source problem must be given a high priority within coastal drainage in the future.**

2. Within the State's existing regulatory program, the geographical jurisdiction of coastal permitting is further limited by the varying jurisdictional constraints of the different types of coastal permits themselves. For example, CAFRA permits are required in a specified CAFRA zone, but not required in the northern coastal counties such as portions of Middlesex and Bergen Counties where Waterfront Development permits are required. Within CAFRA jurisdiction, Waterfront Development permits are required only for various types of development in the zone from the mean high tide and seaward. In the northern counties, Waterfront Development permits are also required along the coast on upland, up to a maximum distance of 500 feet inland from the mean high tide line. The manner in which the programs overlap has led to some peculiar situations. For example, because CAFRA permitting excludes smaller developments, development up to 25 residential units can be constructed throughout the CAFRA zone and directly along the coast and need not obtain any sort of coastal permit--neither a CAFRA nor a Waterfront Development permit is required. In the Fall of 1988, Governor Kean signed an emergency rule, which now has been made permanent, requiring NJDEP to review "any substantial first use" of waterfront property, regardless of size. This additional rule applies only to areas adjacent to tidal waters. Although a portion of the regulatory loophole has been closed as a result, the majority of the loopholes remain insofar as the Atlantic coastal drainage is concerned.

> "Prior to the adoption of the emergency rule, development in these coastal areas was regulated mainly by the CAFRA law, which does not regulate developments of fewer than 25 units and most commercial development. All construction or development activity requires a permit under the Waterfront Development law, but before this change the law did not apply to the CAFRA area except at or below the mean high water line.
>
> "DCR Director Weingart said, 'Many people are under the mistaken impression that the rule constitutes an absolute moratorium on construction in the CAFRA waterfront area. In fact, the division has approved permits under the emergency rule, although more stringent standards are applied in environmentally sensitive areas.' Also, no permits are required for reconstruction of a building that is destroyed by storm or fire provided the use of the building does not change.

Similarly, any building expansion or enlargement of fewer than 1,500 square feet does not require a permit."

("Environmental News," NJDEP, January/February 1989)

Coastal permits are not required for agricultural, silvicultural, and various other types of activities, new or existing. Although a detailed analysis of the amount of these types of activities within Atlantic coastal drainage has not been conducted for this Manual, it is not believed that these sources of nonpoint pollution constitute major sources of pollution at the present time. Nevertheless, they are responsible for some unknown amount of pollutant loadings which cannot be affected by the coastal permitting program as it is currently defined.

Although there originally may have been a program rationale behind permit jurisdictional inconsistencies in NJDEP's current coastal regulatory program, these inconsistencies, omissions, and loopholes are baffling in the present reality, and serve to weaken the nonpoint source water quality effectiveness of the program.

3. Even within the existing regulatory jurisdiction of the coastal permitting program, coastal permits are not required for all new development projects. In other words, even though CAFRA permits are required for new residential land developments within the CAFRA zone, only certain types of projects--basically, large projects--must apply for a permit. As a matter of fact, we demonstrate here that in many cases the data suggests that the majority of new housing units constructed within the CAFRA zone are not managed, controlled, or in any way affected by the CAFRA, Waterfront Development, or Wetlands permit programs (note that although the data below have been compiled prior to the issuance of the emergency rule discussed above, this recent change in the program will not appreciably change the statistics presented in tables below).

For example, within CAFRA, you can pave up to 3 acres or an area with up to 300 parking spaces without a permit. You can build up to 25 dwelling units without a CAFRA permit. You can build any number of nonresidential commercial, retail, manufacturing, and other types of facilities without a CAFRA permit. Consequently, it is apparent that while the CAFRA program affects <u>some</u> new development, many--possibly even the majority of--new development projects <u>even within the permit geographical jurisdiction</u> are not being affected by the permit program. The accompanying Tables 7 through 14 demonstrate this reality all too vividly. In the case of Atlantic County, only 1,573 dwelling units (29.2 percent) can be accounted for in the 1985-7 CAFRA file, whereas total dwelling units authorized for construction were 5,382, according to the NJ Dept. of Labor data. For Monmouth County, the numbers are 444 and 2,093 respectively (21.2 percent); for Ocean County, 5,139 and 17,896 (28.7 percent); for Burlington County, 0 and 10.

In other words, the statistics suggest that only about one-quarter of the total number of dwelling units constructed within the CAFRA area were subject to CAFRA approvals.

For nonresidential CAFRA permits, the situation appears to be even more dire. Based on an indepth look at several Ocean County municipalities during this 1985-7 three-year period, we find that the vast majority of nonresidential land development authorizations were not part of the CAFRA permitting process. In Brick Township, for example, County records show that 142 different nonresidential developments were given final approval during this period, involving 583.4 acres with 1,819,800 square feet of building area. Parking and other paved surfaces, of course, for these developments would be considerable. The CAFRA coastal permitting file lists only 3 developments, including one nursing home, one hospital support facility, and one retail commercial development (Table 15).

A somewhat similar case can be made for Waterfront Development permits, where various types of development, typically the smaller development projects, are excluded (our greater concern in the Waterfront Development arena relates to the fact that the band of geographical jurisdiction here is so extremely narrow, constituting only a slight percentage of the area producing or potentially producing nonpoint source water quality pollution).

Thus, the coastal permit program appears to be missing tremendous amounts of both residential and nonresidential land development activity <u>even within its existing geographical jurisdiction.</u>

4. Within the universe of CAFRA jurisdiction and CAFRA permits issued, we believe that nonpoint source water quality considerations are not evaluated thoroughly and that, therefore, appropriate mitigative measures are not being required as part of the program. Our judgment here reflects our understanding of the coastal permitting program which, with its many environmental objectives, has not been established as a vehicle for nonpoint source water quality management. We have scrutinized the many location policies, resource policies, and use policies which comprise the program. Under location policies, we have scrutinized both Special Area and General Area policies and concluded that nonpoint source relevance of most of this program guidance is indirect at best. For example, Special Area policies 3.2 (Shellfish Beds) through 3.25 (Wetlands) are important ecologically, but their application is so focused that nonpoint source relevance is minimal. Policy 3.26 (Wetlands Buffer) is interesting in that it discourages development within 300 feet of a wetland area. Policy 3.30 (Intermittent Stream Corridor) discourages disturbance adjacent to swales and ephemeral stream corridors and has nonpoint source water quality benefits. However, taken as a whole, the total of these Special Area policies does not in any way constitute an effective nonpoint source water quality management program for CAFRA zone development projects (these and other policies are addressed in greater detail in Appendix A where several actual permits are reviewed).

Both construction phase and operation phase nonpoint loadings are in no way managed by these Special Area policies.

Of potentially greater relevance are the General Area policies, as integrated into the CLAM or Coastal Location Acceptability Method. The "bottom line" of this procedure is a set of criteria specifying maximum impervious cover for developments within CAFRA jurisdiction. The CLAM system is predicated on designation of coastal growth ratings, environmental sensitivity ratings, and evaluation of development potential, all of which are brought into overlay for determination of the acceptable intensity of development. In application, high intensity developments with maximum impervious cover of up to 80 percent (pervious paving of up to 90 percent) are allowed in development regions where environmental sensitivity is either low or medium and where development potential is either high or medium. Although in the abstract the extent of this area cannot be readily estimated, high intensity development could be acceptable within large areas of the CAFRA zone, given the fact that the development and extension regions comprise by far the bulk of the CAFRA zone. Also, environmental sensitivity as defined here is quite delimited in focus and is a function of forest vegetation, depth to water table, and rapid soil percolation rate.

In short, it is possible that extensive undeveloped areas, subject to substantial growth pressure and within the CAFRA zone, could be

Table 15. Case Study: Brick Township, Ocean County Nonresidential Development, 1985-87 (Cahill and Associates, 1988 Based on Ocean County Planning Board Annual Summaries)

Brick Township

1985 Name	Lot Size (ac)	Bldg. Size (sq. ft.)	1986 Name	Lot Size (ac)	Bldg. Size (sq. ft.)	1987 Name	Lot Size (ac)	Bldg. Size (sq. ft.)
Capi.	1.00		4 Seasons	0.30	1,451	Bank	2.00	17,820
Dorado	2.80	1,500	Parkwood	7.70	60,700	Motel	1.70	6,642
Medical	0.90	6,861	Cedar Bridge	19.60	56,675	Realty	6.30	125,000
Castrodos	0.80	5,000	Exxon	1.50	1,104	Miller	0.90	7,105
Bricktown	0.70	9,880	Sandpiper	3.80		Flower	15.00	
Addition	10.80	1,596	Retail	0.60	6,188	Retail	0.65	5,000
Prof.	5.70	13,880	Prof.	0.40	3,528	Scanite	1.90	
Gas	1.30	3,541	Retail	0.40	16,000	Office	0.80	6,000
Retail	1.20	11,160	Retail	2.10	14,950	Mantolok.	4.10	13,030
Marine	9.40	16,025	Drum	5.60		Goldstein	2.40	36,000
Service	0.70	378	Brick	1.90	16,293	Brick	33.10	1,934
Van Barn	0.70	3,880	Academy	0.50	2,500	Howell	0.60	1,820
Chambers	0.90	2,369	Cranberry	1.20		Retail	0.70	3,880
Creative Design	0.20		Misc.	10.80	17,360	Misc.	2.30	20,500
Retail	7.60	28,488	Mobil	0.30		St. Dom.	16.90	6,051
Prof.	0.40	3,599	Bay		3,161	Lions	5.70	
Kennedy	6.10	4,970	Prof.	0.50	1,400	Lions	5.80	19,840
Auto	1.00	5,182	Add.	0.80	4,750	DDS	0.50	490
Condo	0.80		Camp	1.60	7,200	Grand	19.80	9,425
Office	6.90	6,587	Rest.	2.70		Milbery	1.00	9,313
Shopping	3.80	31,367	Paul's	0.40	3,000	E&A	2.60	5,700
Office	0.40	3,240	Retail	4.20		Jiffy	31.70	
Chicken	0.60	2,336	Retail	2.20	15,600	Crest	1.80	17,265
Stereo	0.60	6,050	Retail	22.60	106,861	Ley	0.30	3,200
Green	0.20	2,196	Herb.	0.20	1,388	Sun	0.20	6,800
Medical	8.30	120,000	Minor	5.70		Laurel	14.50	128,726

Case Study

Channel	12.80	97,600
Misc.	0.20	2,100
Comm	0.60	6,187
Misc.	2.90	
Prof.	0.80	4,000
Bank	0.90	3,016
Caldor	9.20	47,461
Industrial	12.70	32,000
Auto	1.90	990
Misc.	0.60	2,835
Used Car	0.20	
Stella	0.70	5,400
Fairmont	0.90	9,936
Real Es.	0.50	4,410
Split	0.60	6,285
Marina	9.60	
Misc	2.60	6,000
Minor	2.20	
Misc.	0.10	515
Flower	0.30	
Retail	1.10	9,600
Retail	2.60	20,800
Retail	0.60	5,800
Limo	0.60	6,100
Industrial	0.90	11,802
Liquor	2.70	9,600
Office	0.50	2,688
Storage	2.30	990
Pizza	0.30	1,800
Misc.	0.40	3,440
Storage	8.70	77,500
Bank	0.60	4,032
Retail	0.30	2,150
	155.70	675,122

Misc.	11.00	48,600
Ret.	0.50	4,557
Cross.	0.40	1,792
Prof.	2.70	700
Vet.	1.30	2,700
Retail	0.70	1,500
Hareston	0.90	11,750
Minor	0.90	
Kath.	1.90	
VFW	0.40	2,100
Kennedy	8.10	29,650
Lions	5.70	
Clipper	9.40	20,000
McDonalds	2.00	855
Minor	32.40	
Jenco	3.20	
United	0.80	2,154
Johns.	6.00	1,800
Law	0.40	
	186.30	468,267

Auto	1.50	7,200
Brick	3.90	
Brick	32.00	585
Golf	1.00	
Cedar	2.70	22,600
Palladino	2.70	30,400
Town Sq.	8.30	44,720
Triple	0.30	3,000
MRN	6.00	52,875
Brick	4.80	51,882
Bay	3.20	2,480
Fire	1.00	9,136
	240.65	676,419

developed at extremely high rates of impervious cover and be granted CAFRA approvals, giving rise to substantial loadings of nonpoint source pollutant loadings.

Secondly, moderate intensity development with up to 30 percent impervious cover (40 percent, if pervious paving is used) is deemed appropriate by the CLAM system in development and extension regions, if development potential is high and environmental sensitivity is high; in extension regions, if development potential is medium and environmental sensitivity is low to medium; and in limited growth regions, if development potential is high and environmental sensitivity is low to medium. Again, though we cannot estimate exactly how expansive this area would be, the area could be quite large, especially given the fact that even the limited growth areas are included here under various circumstances.

Furthermore, these General Land Areas policies are set aside under certain circumstances, such as Large-Scale Multi-Use Developments (a Use Policy), involving at least 500 dwelling units. In these particular situations, impervious cover limits are voided in all sub-categories of Development and Extension regions, as well as in Limited Growth regions with low environmental sensitivity (3 sub-categories with varying development potential). In Limited Growth regions with medium to high environmental sensitivity, development potential criteria are also liberalized. The Division of Coastal Resources permit review section staff has identified various developments which have relied upon this Use policy, especially concentrated in various Ocean County communities. If cover requirements are to be liberalized in these large-scale projects, rigorous performance standards should be imposed in terms of both stormwater quantity and quality, so that water resource impacts are not exacerbated. Given the fact that these developments by definition tend to be quite large, involving large sites with added potential for planning and engineering flexibility, adherence to special stormwater quantity and quality performance standards would seem to be quite reasonable.

Nonpoint source water quality issues are most directly dealt with under Resource Policies, Policy 8.7 (Stormwater Runoff). Also, Policy 8.4 (Water Quality), prohibiting any coastal development which "...would violate the federal Clean Water Act, or State laws, rules and regulations adopted pursuant thereto..." is theoretically applicable; this policy is extremely generalized and, based on case study review and experiences with NJDEP staff, is not being operationalized at present, although the policy clearly sets the stage for a much more comprehensive nonpoint source water quality program to be developed. Under the runoff policy, there are special provisions for flood and erosion control which are basically quantitative in nature, requiring that the pre-development 2-year, 10-year, and 100-year storm peak rates of runoff are not exceeded by post-development rates. The supposition behind this aspect of the policy is that detention basins will be constructed and maintained. From a water quality perspective, these basins will have some modest water quality function in terms of the settling out of particulate pollutants; however, the primary basin function, even if properly maintained, is a quantitative one--the reduction in peak rate of runoff and prevention of onsite flooding. Single-purpose detention basin construction has little, if any, water quality benefit and must be accompanied with quality-oriented BMP's (ideally, replaced with BMP's which offer both quantity and quality control).

Other water quality controls are also specified in 7:7E-8.7 Stormwater Runoff (b) 2(i): "...at least 90 percent of the total 1-year storm runoff must be detained in the detention basin for a minimum of 18 hours for residential developments and for 36 hours for nonresidential developments." Alternatively, if the soil water table permits, a plan yielding zero production runoff for the 1.25 inch-2 hour storm will also satisfy any water quality-related runoff requirements here. These provisions, if thoroughly applied, would make an important reduction in generation of particulate nonpoint source pollutants throughout coastal permitting. A substantial amount of pollution in particulate form would settle out and be prevented from leaving the typical site. Depending upon the context of the development and the measures being proposed, some combination of ongoing maintenance requirements would also be necessary and should also be addressed within this policy (NJDEP's Division of Water Resources is knowledgeable in this area). Unfortunately, some particulate pollution would escape from this system by its very definition; pollution from major storm events, of course, would not be contained. Possibly more serious would be the insensitivity of the system to solubilized nonpoint pollution such as nitrate and ammonia nitrogen. Nevertheless, this policy is a useful first step in nonpoint source management control in the coastal zone.

Based upon review of coastal permit approvals, however, this particular policy does not appear to be given adequate emphasis. In fact, in many instances, possibly a majority, these quality requirements appear to have been ignored. In many situations, permit reviewers do take the opportunity to impress upon applicants that all available measures to maximize groundwater recharge and minimize runoff should be taken. Various techniques which have quality ramifications are only generally alluded to. Specific requirements are not identified and imposed, especially in the quality area, as often as they should be.

Based on our information gathering to date, an "unofficial" set of nonpoint source mitigative measures and best management practices sometimes is recommended by Coastal Resources staff as part of the permit review process, subject to the experience of the reviewer and guidance by senior staff. These measures might include the recommended use of recharge systems where suitable, roof drain discharge to sub-surface beds, drainage system components which exfiltrate into the soil, vegetated sediment ponds and other measures which serve to reduce the quantity and improve the quality of direct runoff from impervious surfaces. These measures are applied on a hit and miss basis, based on what can be extracted from the applicant or his engineer. Although water quality requirements do appear to be getting more rigorous, there remain serious gaps in the program.

In summary, within the jurisdiction of CAFRA and coastal permitting and within its management scheme, remarkably intense developments, generating potentially large nonpoint source pollutant loadings of various types, are acceptable under present guidelines. They have been approved in the past and will continue to be approved in the future, even with recent modifications to the coastal regulatory program. Furthermore, even within those areas where CAFRA density controls are most rigidly applied and maximum acceptable intensity of development is limited to 3 percent (5 percent if pervious pavement is used), nonpoint source pollution is not necessarily avoided. Whereas impervious cover certainly does have nonpoint source water quality significance, other nonpoint source pollutants in the form of nutrients, fertilizers, herbicides, pesticides, and so forth can be generated by highly pervious development (e.g., golf courses, expansive retirement communities, and the like). Consequently, the coastal permitting program as it is currently structured has only a modest and indirect nonpoint water quality relevance, even in the most rigorously managed areas.

Other Relevant NJDEP Regulatory Programs

Because this coastal program relates directly to both stormwater management and nonpoint source control, it is important that any program undertaken by the Division of Coastal Resources be compatible with stormwater management programming as is currently being implemented within the Division of Water Resources (DWR). Consequently, some summary description of this related effort is in order.

The State's stormwater management program was enabled by the New Jersey Stormwater Management Act (P.L. 1981, c. 32) and the related regulations (N.J.A.C. 7:8-1.1 et. seq.). The program is being implemented by both municipalities and counties, although mandatory stormwater management is contingent upon NJDEP's distribution of 90 percent study grants to cover the costs of the necessary planning. This program, being administered by the Division of Water Resources, is proceeding as rapidly as resources allow. However, it will be a considerable number of years before all 567 municipalities throughout the State have been included in the program, even under the most optimistic of scenarios. It will be even longer before all watersheds have both Phase I and II planning completed. There are a variety of aspects to the State's stormwater management program which need to be highlighted here:

1. The program defines Phase I and Phase II planning processes. In Phase I, high priority municipalities may apply for $5,000 grants to prepare/adopt a municipal stormwater management ordinance, which establishes onsite quality and quantity controls for stormwater management. Phase II grants are for detailed watershed planning studies to be done by counties or municipalities, usually resulting in the identification of locations for regional or areawide basins which are to be designed to mitigate synergistic peak flooding effects within the basin or sub-basin.

2. The Phase I program focuses on control of particulate pollution, including hydrocarbons, from the one-year, 24-hour storm or the 1.25 inches in 2 hour storm (the settleability design storm) <u>for new development.</u> Stormwater must be detained and emptied slowly in no less than 36 hours for nonresidential areas and no less than 18 hours for residential areas. The program is <u>not</u> oriented around dissolved pollutants such as nitrates. In Phase I, respective municipalities must incorporate this performance standard into their existing ordinances, in addition to the standard of not increasing the peak rate of flow for the 2, 10, and 100-year storms, assuming no tidal domination

3. Due to the State's stormwater program standards, the typical physical BMP associated with the program is the dual-purpose detention basin or extended detention basin, ultimately to be located both onsite (after Phase I) and regionally on an areawide basis to provide greatest effect (after Phase II planning has been completed).

4. Within the coastal drainage area of concern here, Phase II concerns regarding synergistic peaking effects and, for that matter, no increase in peak rates for the 2, 10, and 100-year storms are of less importance. If the site drains to completely tidally dominated drainage, these concerns are irrelevant and need not be addressed. As distance from tidal domination grows greater, concerns for onsite peaking and synergistic peaking increase and should be given greater priority and, therefore, Phase II planning is of increasing importance. Participation in these regional basins

could be operationalized through a scheme of user fees, possibly based on a site's contribution to the 100-year peak flow increase.

5. The State's thrust necessarily seems to be to incorporate as many high priority municipalities into the Phase I program as quickly as possible. Participation in the program is voluntary at the present time; furthermore, we understand that there is a waiting line to gain admission into the stormwater management program. Therefore, it may be quite a few years before Phase I planning is completed throughout all municipalities, if it is completed at all. It appears as though it will be many years before the detailed engineering needed for Phase II planning can be supported throughout the State.

The State stormwater program is designed to be flexible (7:8-3.2 Flexibility of approach) and can be integrated into a program with additional stormwater requirements within coastal drainage. For example, the regulations acknowledge that where soils have sufficient permeability, zero production of runoff from the 1-year storm, accomplished possibly through various infiltration techniques, wet ponds and artificial marshes, or porous paving and other techniques "...will be considered sufficient to meet the water requirement for residential developments, provided that the seasonal high groundwater does not rise to within two feet of the bottom of the detention facility. For other than residential developments, approvals will be on a case-by-case basis after technical review by the designated authority. The object of this review will be to avoid pollution of the groundwater." [7:8-3.4 (a)(2) (ii)]. Based on recent meetings, it is our understanding that NJDEP's Division of Water Resources wants this criterion of a 2-foot separation to be increased to 4 feet and intends to work to have this criterion so modified. This concern relates to the State's concern that stormwater runoff will contaminate groundwater supplies now and in the future. Of greatest concern is stormwater incident to paved areas, especially in nonresidential developments where traffic volumes are greater and hydrocarbon and heavy metal production levels would be greater. This concern increases in importance in areas dependent upon groundwater for their water supply and becomes more critical as depth to water supply wells decreases.

In most situations, it is possible to conceive of the program of recommendations being developed here for the Division of Coastal Resources as a special set of directions which overlay onto the program being developed through the State stormwater management program. Because this coastal program is oriented around both particulate and dissolved pollutants, the differences are less a function of outright incompatibility than of an additional focus. Consequently, our goal here would be to make any additional Coastal requirements readily adaptable to the existing statewide stormwater management program.

The State's wetlands programs, both coastal and freshwater, are vital and contribute in important ways to maintenance of overall water quality within the Atlantic coastal drainage. However, neither wetland program has substantial net effect on nonpoint source water quality pollution within coastal waters. The wetlands permitting programs regulate new development activity within mapped wetlands areas. The overall effect of the regulations is to discourage new construction activity of all types within wetlands, but especially any type of activity which is not water-dependent. These negative incentives are provided through the permit process itself, as well as mitigative measure requirements, including the replacement of 2 acres of wetlands for each acre filled/affected. From one perspective, this program does have considerable beneficial effect on water quality--preservation and maintenance of wetlands, of course, is vital to overall water quality. However, given the tremendous amount of new development which has occurred and will continue to occur in nonwetland areas, the wetlands programs are rather marginal in performance in terms of nonpoint source water quality, given the modest amount of construction and area involved.

Furthermore, the fact that water-dependency is favored as a use does not in any way guarantee that nonpoint source pollutants will be minimized.

On the Federal level, there are no effective nonpoint source regulatory programs operating in New Jersey at the current time, although additional regulations are pending. The 1987 amendments to the Federal Clean Water Act mandate Federal regulation of stormwater through the existing National Pollution Discharge Elimination System (NPDES). Stormwater "point sources" have been categorized by these Act amendments as follows:

- o stormwater point sources which are significant sources of pollution
- o industrial stormwater point sources
- o stormwater systems for municipalities with populations greater than 250,000
- o stormwater systems for municipalities with populations between 100,000 and 250,000
- o other stormwater sources, including smaller municipalities, commercial areas, office parks, etc.

Congress assigned EPA specific deadlines for conducting additional studies, developing further regulations, issuing permits, and establishing a permit compliance system. For industries and municipalities over 250,000, EPA is to have issued all regulations and procedures and requirements for stormwater discharges by February 4, 1989, is to have received all necessary NPDES applications by February 4, 1990, is to have issued all necessary NPDES permits by February 4, 1991, and is to have achieved the necessary permit compliance actions by February 4, 1994--a very ambitious schedule. For municipalities between 100,000 and 250,000, these respective deadlines are moved back two years. For all other stormwater point sources, EPA has until February 4, 1992 to further study program requirements. EPA issued proposed rules on November 30 which, on the one hand include both the "over 250,000" and "100,000 to 250,000" category of municipalities as well as businesses with stormwater discharges. These proposed rules, however, apply only to approximately 170 incorporated municipalities, excluding, according to the Natural Resources Defense Council, another 410 counties with such populations. Furthermore, there are no municipalities within Atlantic coastal drainage that would fall within this category. The rules are subject to a public comment period and to revision. It remains to be seen just how rigorous EPA will be able to be in setting water quality standards for these various stormwater discharges and in enforcing these standards. One possible approach which the Agency has considered in the past would be <u>pollutant</u> specific, as used in the NPDES program for wastewater discharges. Alternatively, another approach could be more <u>performance</u> oriented, focusing on, for example, management of the first 1 inch of rainfall. Important aspects of EPA's program appear to be mapping of existing storm sewer systems, developing programs to eliminate illegal discharges into these existing municipal storm sewer systems, attempting to implement a program of feasible BMP's within the existing systems, and imposing broader standards on new development. This EPA program, in sum, should reinforce State efforts in the coastal zone, although it will obviously be some years before these EPA regulations have any real impact on the coastal drainage itself.

We would strenuously urge the State to advocate EPA's establishment of stringent water quality standards and stormwater discharge criteria in all coastal waters in order to guarantee adequate protection of our coastal resources. If such standards were to be mandated nationally, not only would coastal waters be protected more uniformly, but it would prevent one state from allowing development to proliferate while other states undertook more responsible water quality programs.

Again, much is made about regulation of wetlands by the US Army Corps of Engineers, so much so that some parties would convey the impression that the Corps is managing overall environmental quality throughout the coastline through their wetlands program. That simply is not the case. The basic effect of the Corps program is similar to that of the State's wetlands regulations, and while important, is of limited significance insofar as nonpoint source pollution is concerned.

On the county and local levels, other programs potentially do exist or are under consideration to affect nonpoint source water quality management. Typically, however, little is being done directly to manage nonpoint source water quality and stormwater runoff qualitatively, as based on review of some county and local practices and discussions with various officials. Nevertheless, the importance of integrating new State requirements with county and local programs cannot be over-emphasized and will have to be dealt with fully and directly.

Based on our evaluations thus far, we draw several conclusions:

o First, the water quality problems plaguing the Jersey coastal waters do not originate just in New Jersey itself; therefore, to the extent that pollutant sources are exogenous, they cannot be managed by New Jersey actions. These external factors, such as acid rain and coastal currents carrying substantial loadings of an array of pollutants from the New York harbor area, clearly must be dealt with on an interstate, if not national basis. Although these external pollutant sources may not be critical in all New Jersey coastal waters (they vary in severity depending upon location along the coast), they are considerable and need to be addressed far more effectively than they have been to date.

o Secondly, water quality problems in coastal waters <u>within the purview of the State</u> are both point and nonpoint source in nature. To the extent that they are point source in origin and reflect wastewater discharges, of course, these problems are not affected by and cannot be affected by the coastal permitting program in any sort of direct way. The real difficulties here are the existing point source discharges, municipal and non-municipal, which need to be upgraded. All of this pertains to a different regulatory area, specifically the NJPDES program, and not the coastal permitting process.

o Thirdly, regarding the coastal permitting program itself, we have found that the geographical jurisdiction of the program is too limited. Water quality management planning must be conducted on a watershed basis for both point and nonpoint sources. However, the geographical limits of CAFRA, waterfront development, and wetland permitting (Figure 23) exclude enormous areas of drainage tributary to coastal waters (Figure 3). If we focus on the direct Atlantic coastal drainage, the total drainage area is 2,059 square miles, with only about 35 percent (847.8 square miles) of that total being <u>within</u> the current regulatory (CAFRA) jurisdiction and 1,211.2 square miles being <u>outside</u> of the jurisdiction. If we look at existing resident population within CAFRA and within Atlantic coastal drainage, we see that these population statistics also bear out this same inconsistency. For example, within Monmouth, Ocean,

Burlington, and Atlantic Counties, existing population within CAFRA was about 615,000 with 520,000 persons outside of CAFRA but within Atlantic coastal drainage (Table 16). If direct drainage areas outside of CAFRA in portions of Camden, Cumberland, Gloucester, Middlesex, and Cape May Counties were to be added to this 520,000 persons, the total excluded would exceed the 615,000 total by a considerable margin. Even more important, based on future population projections, considerably more growth is expected to occur outside of the CAFRA zone, than within the CAFRA zone, although growth in any case is expected to be considerable. Although resident population is not a precise substitute for land use and nonpoint source water quality loadings, these data do provide further demonstration that there are very substantial areas, with very substantial amounts of existing and projected land activity, which are beyond the influence of the coastal permitting program as currently defined.

In other words, we must acknowledge the reality that regardless of what we propose here in the way of improved water quality-oriented best management techniques to be applied throughout coastal permitting, all nonpoint source loadings occurring in the drainage beyond coastal permitting jurisdiction--over 1,200 square miles which comprises the bulk of the drainage area--will by definition be unaffected and will continue to degrade river and streams, back bays, and ultimately ocean waters. Either the coastal permitting program should be expanded geographically to include this drainage area, or efforts should be made to guarantee that other programs (such as the NJDEP Stormwater Management Program), or local levels of government provide nonpoint source management necessary to maintain coastal water quality. Actions which could be taken would include making the State's stormwater management planning compulsory on the local level with dramatic increases necessary for additional municipal subsidies. Also vital would be expanding the scope of the State's stormwater management program to include solubilized, as well as particulate form stormwater pollutants.

Urbanization and Future Land Use

The development of New Jersey coastal areas has been nothing less than overwhelming during the past thirty years. While the barrier islands of central and southern coastal New Jersey have served as a resort area for more than a century, it has only been within more recent times that extensive, permanent communities have mushroomed along the mainland, creating a proliferation of settlements such as LeisureTowne and Smithville around older towns such as Toms River and Atlantic City. The permanent nature of these developments, such as in Ocean County, is largely related to serving an older retired population, and the demographics are unique. One particular land use ramification of this trend is the construction of extraordinarily large retirement communities--planned developments, where site planning, landscaping, and maintenance are managed on a total site basis. Such situations offer special potential in terms of the introduction of stormwater best management practices (BMP's).

Table 16. **Existing and Projected Population within Atlantic Coastal Drainage, within and outside CAFRA Zone (Cahill and Associates, 1988)**

	Within Coastal Drainage within CAFRA	Within Coastal Drainage outside of CAFRA		Within Drainage within CAFRA	Within Drainage outside of CAFRA	
Counties (1)	Existing Population	Existing Population	Total	Projected Population	Projected Population	Total
Atlantic (2)	136,286	57,909	194,195	186,899	98,085	284,984
Burlington (2)	920	15,344	16,264	1,260	20,705	21,965
Monmouth (2)	184,414	330,623	515,037	193,036	400,737	593,773
Ocean (2)	293,292	115,841	409,133	366,850	181,550	548,400
Total	614,912	519,717	1,134,629	748,045	701,077	1,449,122

(1) This table does not include all counties within Atlantic drainage and the CAFRA zones. Small portions of Middlesex County are excluded, as are Burlington, Camden, Cumberland, Salem, and Gloucester. Delaware Bay drainage counties have not been included, nor has Cape May County, the bulk of which flows into either Delaware Bay or the Atlantic Ocean. The rationale behind the table here is several fold: to bracket the sizable population totals both existing within Atlantic drainage and projected within the same area; to make clear the large proportion and absolute amount of growth expected that falls outside of CAFRA jurisdiction. The table is based on the same summary assessment of municipalities used in prior county tables where 100%, 75%, 50%, 25% of municipalities were tallied, based upon our judgment of land area weighted by our knowledge of population distribution. No actual dwelling unit counts were performed.

(2) Existing and projected population by county are for different years, depending upon source, and are as follows: Atlantic County, 1980 and 2005; Monmouth County, 1987 and 1995; Ocean County, 1986 and 2000; Burlington County, 1987 and 2010. References are as given in the respective county tables.

The fact that the area within Atlantic coastal drainage is heavily oriented toward a seasonal tourism industry has also influenced land use and led to patterns which are somewhat atypical. There are far more hotels, motels, restaurants, and other tourism-serving uses along the coast than would be expected in other non-tourism oriented zones. Tourism, one way or the other, can be expected to continue to be a major factor here, and land uses will reflect this influence.

The casino industry, of course, has had a major effect on Atlantic County and surrounding areas, generating substantial new "basic" employment and giving rise to other related employment, not unlike some sort of new manufacturing facility. Although it seems highly unlikely that the next 20 years will experience anything like the growth and development related to casinos which has occurred thus far, new projects continue to be considered and may well further stimulate these local economies, with attendant land development related stormwater effects.

Population and growth projections for counties comprising Atlantic coastal drainage (excepting Cape May County, where NJDOL projections show an increase from 89,000 in 1984 to 126,300 in 2010) have been presented (Tables 7 through 16) and discussed. These projections reflect continuation of the dramatic growth pressures currently being felt and which have been felt for some time. Most of this growth can be expected to occur within coastal drainage, in areas draining directly to the ocean as well as to streams, rivers, and back bays which drain into ocean waters. Because most of the barrier islands themselves are at this point largely developed, growth and development can be expected to be relatively limited in areas directly draining to the Atlantic Ocean, with the exception of scattered infill residential and some commercial redevelopment projects at increased densities.

In Ocean County, for example, growth projections for the County are astronomical, but the barrier island communities can be expected to absorb relatively little of this new development. Most growth will occur in mainland townships, on large upland sites at ever-increasing distances from the shoreline. Although a substantial amount of this growth along the coast may not be contained within the existing CAFRA jurisdiction, this development definitely will occur within the Atlantic coastal drainage, generating nonpoint source water quality impacts on stream, river, back bay, and ocean waters.

Because of the varying hydrodynamics of both the Delaware Bay and Hudson-Raritan Bay complexes, less emphasis has been given here to nonpoint source control issues and management practices within the drainage areas tributary to these Bays. In the "northern waterfront" areas of Bergen and Hudson Counties, substantial redevelopment, both residential and commercial, is occurring in areas immediately adjacent to the Hudson River, such that municipalities here will experience tremendous population growth. Fortunately, because much of this development is waterfront development, a good portion of this construction is subject to Waterfront Development permitting. Elsewhere in these counties, growth is expected to be far more modest; in some older areas, population is expected to continue to decline considerably, although in many areas continued nonresidential development may take place. According to the New Jersey Dept. of Labor and their preferred projection set, Hudson County is projected to decline in population from 1984's Census estimate of 558,600 to 507,300 in 2010 with even greater declines projected thereafter.

The situation becomes dramatically more complicated if the geographical scope of the analysis is broadened to include all areas in New Jersey draining into the Hudson-Raritan Bay (basically all of north Jersey) plus New York State, where growth and development trends are extremely complex. Middlesex County, for example, contains older areas experiencing serious decline, as well as rapidly urbanizing zones, both of which have their own set of nonpoint source water quality problems.

We have not undertaken here a detailed population projection and future land use analysis of Atlantic coastal drainage per se, or of areas tributary to the Bays. However, based on information gathered thus far, we are confident in concluding that additional growth and development within coastal drainage--both within and outside of CAFRA and coastal permitting jurisdiction--will be great and will have comparably great nonpoint source loadings, above and beyond what is already flowing into coastal waters.

Current Stormwater Management Practices in the Atlantic Coastal Drainage and Beyond

The preceding sections have discussed the specifics of the Division of Coastal Resource's existing coastal regulatory system, as well as the New Jersey stormwater management program, which is very much in its infancy. It should be recognized that there has existed a fairly rigorous stormwater management program within the State since 1974, when the New Jersey Soil Conservation Committee published *Standards for Soil Erosion and Sediment Control in New Jersey,* a compendium of design guidelines for a variety of BMP's, both vegetative and structural, which addressed the issue of sediment pollution. This set of standards, focusing primarily on erosion and sediment (E &S) control, has been incorporated into or is referenced by most municipal ordinances within Atlantic coastal drainage and beyond and over the past 14 years has become the standard for water quality control in development planning. As a result, virtually all municipal ordinances are structured around the concept of attenuation of peak rate of runoff rate, typically requiring stormwater detention for this purpose. E & S controls are usually also required as part of the site development plan and provide a limited measure of nonpoint source pollutant reduction during construction.

Throughout this Manual, relatively little attention is paid directly to municipal regulation, which is not to imply that the municipality does not play a vital role in nonpoint source management. Given the essential municipal role in land use regulation, for example, municipalities are intimately connected to nonpoint source water quality issues. At the county level, there is some consideration of water quality impacts associated with the land development process. For example, the Ocean County Subdivision and Site Plan Resolution (as amended 2/4/87), adopted pursuant to the New Jersey County and Regional Planning Act (NJSA 40:27-1, et seq.), provides for review and permitting of land development applications by the County Planning Board, as those projects affect County transportation and drainage facilities. Within the referenced guidelines are specific design criteria which emphasize groundwater recharge of stormwaters, with the exclusion of excessively drained soils. Water quality is addressed in Section 514 by retention of small storm runoff for 18 to 36 hours, a criterion consistent with NJDEP guidelines for dual purpose detention basins.

For the most part, current stormwater ordinances at the municipal level deal primarily with the hydraulic and hydrologic aspects of stormwater, other than the E & S criteria which are incorporated in the construction guidelines. Some reflect an awareness of groundwater recharge considerations, but none incorporates specific water quality criteria in the ordinance.

CHAPTER 3.

STORMWATER AND POLLUTION

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STORMWATER AND POLLUTION

Nonpoint Source Pollution

During the past twenty years, the United States has invested over 58 billion dollars in public and private monies to reduce the discharge of pollutants into our rivers, lakes, and coastal waters. This massive effort reflected a national commitment to restore water quality to healthful levels. As an expression of the public will, few programs in our history, outside of military conflicts, have enjoyed such a commitment of resources. The Federal Water Pollution Control Act of 1972 laid the foundation for a massive cleanup of polluted waters discharged by town (municipal treatment plant point sources) and industry (private point sources) to virtually every water body in the nation. One need only compare the discharge of municipal wastewaters to the coastal environment of New Jersey in 1977 with the present upgraded and expanded municipal treatment systems to appreciate this investment in public works. A tremendous amount has been accomplished in terms of sewage treatment.

That landmark legislation, and the funding program which has supported it, has done much to accomplish the intended water quality objective. The necessary wastewater treatment facilities have been built for urban centers, large and small. The industries which discharged a vast array of pollutants in their process waters, from paper mills and steel mills, refineries and factories have, by and large, done their part to dramatically reduce and in some cases largely eliminate the waterborne residue of their manufactured products. Not all point sources have been brought into compliance, but pollutant loadings have been reduced significantly across the country.

The focus of this effort to restore water quality over the past 20 years has been on the municipal sewer systems and industrial process water flows which directly discharge their residual pollutants, via a pipe or conduit, to some natural stream channel, mixing these wastewaters with the natural flows of the river, estuary, or in the case of coastal New Jersey, the near shore ocean waters. As these specific discharges into a waterway were located and documented, and their impact on the receiving water body analyzed, their location came to be identified by the actual point of wastewater discharge into the natural drainage system. Thus, the term "point source" was applied to each outfall. Listings of point sources within a river basin were developed and became the first priority for corrective action.

Historically, point sources have been considered the major water pollution problem in New Jersey. With over 1,500 permitted wastewater discharges in place (with a 60 to 70 percent compliance record), plus 655 hazardous waste sites, the State's waters carry more than their share of residual wastes. The Statewide water quality inventory or Section 305b report (NJDEP, 1988) suggests that surface waters experience their worst water quality conditions during low-flow summer months, but does not distinguish between the various pollutants by origin. Thus, the evaluation as to whether the water quality in a stream or lake is dominated by these specific wastewater discharges is somewhat judgmental in nature, (interview with Kevin Berry, NJDEP, 8/17/88) with very few watersheds studied in sufficient detail to separate the specific causes of water quality degradation. As for coastal waters, the data is even less specific and the conclusions more vague.

As we have undertaken this concerted effort to restore quality to our water resources, it has become painfully apparent that our efforts fall short of the stated goal in many river and estuary systems. This has not been due to a lack of stringent criteria or available treatment technology, as both have been thoughtfully developed and applied. Rather, it confirms the fact that we have neglected to deal with a significant portion of the pollution problem.

The reality of our present water quality is that while much of our residual wastes are now processed by modern treatment facilities, we also introduce a significant amount of pollutants to our water systems by a variety of activities which do not result in a direct and easily identifiable point discharge. During precipitation periods, runoff from many sources, such as agricultural fields, lawns, city streets, landfills, factories, and roads carries pollutants into streams and coastal estuaries. The magnitude of these uncontrolled pollutants can be measured in a river system by estimating the total pollutant load produced in a drainage area and subtracting the load from known point sources. The net balance of pollutants is classified as "nonpoint source" (NPS) pollution. These nonpoint pollutants are transported through a watershed as a part of stormwater runoff and are not continuous. By comparison, the point source pollutants are continuous discharges, usually impacting a water body most severely during its lowest flow condition. Thus, the full range of hydrologic and chemical conditions must be evaluated to distinguish between these two very different types of pollution sources.

Even though hundreds of lakes are impacted by NPS pollutants across New Jersey primarily by sediment and phosphorus, detailed scientific data is limited to only a few of these lacustrine systems. Since 1984, additional water quality data in lakes has been limited to 12 on-going lake restoration projects around the State, totalling less than 2 million dollars. These activities usually take the form of dredging and shoreline stabilization. In Mercer County, for example, Etra Lake is being dredged under this program, at a cost of some $0.5 million. Nearby Colonial Lake is under consideration for a similar dredging effort, at a cost of $2 million. This rehabilitation program, however, has limited resources and is limited to public water bodies. Private lakes must look to their own resources for any physical restoration or removal of accumulated sediment and nutrients.

While most of the capital investment currently being made in New Jersey to correct nonpoint source pollution is directed toward lake restoration, the estuaries of the State, especially in the Hudson-Raritan estuary and the Delaware estuary, are severely impacted by a mix of point and nonpoint pollutants. Much of this loading continues to be point source, including the discharge of sanitary sewer systems and industrial wastewaters. However, the impact of combined sanitary/storm sewers and their discharge during storm events results in severe pollutant loading from combined sewer outfalls (CSO's) in many of the older urban communities. The waters of the Authur Kill, the Hackensack River, and Newark Bay are severely polluted, and it has been concluded that a significant part of this contamination is attributable to the point sources discharged via the nonpoint source storm sewer systems.

Virtually all of the focus of attention related to nonpoint sources has been concerned with the obvious impacts on surface water systems, especially lakes. The flow of sediment from a cultivated field into a stream or lake is obvious, even if the nutrient which is moving with the sediment is not so apparent. The resultant green slime which covers the lake in late summer, however, is proof enough that the nonpoint pollutant phosphorus has been carried from the land surface, stimulating excessive algae growth and ultimately resulting in degraded water quality. NPS pollution is much more than a temporary pollution condition. It impacts the health of our communities by impacting public and private water supplies, reducing the recreational use of our lakes and beaches, and degrading aquatic habitats essential to fish and shellfish. Existing data indicates a worsening of NPS pollution in most water resources of New Jersey and makes obvious the need for action to reduce these pollutants.

The common element of all such nonpoint source pollutants is that they are usually conveyed into our natural drainage systems during the process of stormwater runoff, or enter the underground aquifers with the infiltrating rainfall. Of course, rainfall has always served to cleanse the land surface, and the organisms which maintain the biochemical equilibrium in a natural water body are well suited to process this detrital influx, from fallen leaves to fallen animals. However, much of the present degradation of water quality in many river and estuary systems is the result of stormwater drainage from our urban streets and cultivated fields, whose pollutant content vastly exceeds the background levels of natural systems which existed prior to manmade intervention.

This nonpoint pollution is based on two simple facts. First, the pollutants conveyed with this stormwater exceed the biochemical tolerance limits of these natural drainage systems and their capacity to assimilate them. Second, we have introduced a vast array of new chemicals and byproducts of our activity, which disrupt the natural balance of the aquatic system or accumulate in certain organisms. The fact that the discharge of these pollutants is intermittent and that the pollutant pathway to the stream is facilitated by our artificial storm drainage systems of inlets and sewers only serves to make the process of nonpoint pollutant reduction more difficult to control.

Surface water bodies, especially lakes and estuaries, have been the recipient of much of this stormwater pollutant flushing action. An estuary has been defined (Pritchard, 1967) as a semi-enclosed coastal body of water which has a free connection with the open sea. In New Jersey, we have several distinct types of estuaries, with varying degrees of flushing action from freshwater inflows and tidal cycle displacement and mixing. The significance of these water bodies with respect to NPS inputs is that they provide an opportunity for particulate settling and chemical uptake, with each system serving as a type of pollutant trap. The removal process may be temporary, as in the utilization of nutrients by macrophytes and plankton, with subsequent consumption by higher elements of the food chain. The death and decomposition process for both plants and the animals which feed on them results in some accumulation in bottom sediments of estuaries and some transport of biomass into the near shore coastal system with each tidal cycle, increased during periods of heavy rainfall and runoff from the upland areas.

For a lake, the pollutant and nutrient trapping process rapidly transforms the water body into an aquatic system polluted by its own excess, with algae blooms and rooted vegetation creating a burden of decaying organic matter which depletes the oxygen levels in bottom waters to a degree where fish mortality results. In an estuary, the settling, enrichment, algae growth, and decay cycle is similar, but in a sense a portion of the pollutant load is displaced with each tidal cycle, ultimately decaying in and depleting the oxygen levels in the near shore environment. It is interesting to note that the anoxic conditions observed in New Jersey coastal waters during previous seasons have not been accompanied by similar conditions in the estuary waters. The relative shallowness of most estuaries allows a substantial oxygen transfer and mixing at the surface, and minimizes the anoxic problem experienced in the deeper waters of the ultimate receiving water body, the ocean. At the same time, the elevated bacterial levels in the estuaries are associated with the increased biomass present in the system, attributable to the flushing of organic matter and nutrients through the estuary.

While water quality scientists working in the New Jersey coastal zone have recognized the need to address this NPS pollution problem for some time, the lack of a clear cut explanation, setting out the exact cause and effect, has hampered regulatory programs. Most importantly, the technical community has failed to convince the general public and their elected representatives of the severity of the nonpoint source problem and its impact on coastal water quality.

One of the continuing data gaps is our inability to accurately measure the specific amount of NPS pollution discharged to coastal waters. The basic method of estimating nonpoint source inputs to a water body or a drainage system is to carefully measure the total flow into the system and sample the chemistry of that flow during dry and wet weather conditions. Since some pollutants (such as phosphorus) increase greatly in concentration during high flows, this distinction is important in order to estimate the total mass transport of NPS pollutants over time. When this sampling and estimate are complete, the known point source inputs are subtracted from the total annual load, and the difference is the NPS input to the water body.

This method is conditional on two very important sets of data: the accurate measurement of stream flow at all points tributary to the system and the corresponding measurement of chemistry at these locations. In the New Jersey coastal drainage, the existing flow measurement stations are situated on the upper reaches of tributaries (Figure 22), and virtually no measurement or sampling of the direct inflows to the estuary systems has been conducted. Even the grab sampling conducted directly in estuary waters has been largely limited to the microbiological data discussed earlier. We have not measured the total discharge of pollutants into coastal waters, other than to inventory the major point sources. Thus, any effort to estimate NPS pollution in New Jersey coastal waters is limited at present to the application of statistics which estimate pollutant runoff from upland studies and other very different drainage areas.

Characterization of Pollutant Types

The pollutants which are grouped together under the general heading of nonpoint pollutants are as diverse in form and chemical nature as any listing of environmental contaminants. They include all of the residual from our activities on the land surface; fertilizers such as nitrogen and phosphorus which drain from cornfields and lawns; dozens of manmade chemicals which kill both animal and insect pests or undesirable plant species; decomposing organic matter which covers our streets, from trash to animal wastes; and the residue from our transportation and energy systems, including oil, grease, metals, lubricants, and other pollutants. For the purposes of this report, some generalizations will be made to simplify the discussion of pollutant production, transport, and ultimate fate in the aquatic ecosystem. Since the hydrologic cycle is a continuum of water movement through the environment, the pollutant impacts occur when these materials pass through this system, affecting the whole spectrum of organisms from microbes to man.

While all pollutants cause a change in the natural biochemical processes, a distinction might be made as to whether a given pollutant is predominantly "biological" or "chemical" in form, duration, and impact. That is, some pollutants result in an overloading or stressing of the natural biological system, exceeding the tolerance limits of the stream, lake, or estuary. These include organic waste materials which produce an increase in natural biochemical processing and result in excessive concentrations of indicator organisms, such as groups of coliform bacteria. Sediment might also be considered a biological pollutant because, while comprised of largely inorganic material, it smothers the benthic habitat (or estuary bottom) and temporarily destroys a vital component of a healthy aquatic system. Other biological pollutants are those chemicals which create an imbalance in the production cycle of the aquatic system, such as the nutrients phosphorus and nitrogen. Here the water quality problem is created by stimulating the growth of aquatic organisms, rather than retarding or killing them, and by causing a shift in species dominance.

Because ocean waters are the ultimate repository of all land runoff, they have assimilated this natural detritus for countless millennia and developed an ecosystem which is dependent on the flow of nutrients and organic material into the coastal aquatic environment. Even the most pristine coastal ecosystem will experience stormwater runoff which contains organic wastes, sediments, and nutrients, but in healthy marine estuaries an equilibrium exists which processes these materials efficiently, resulting in the development of useful biological communities, such as finfish and shellfish. In the coastal waters of New Jersey, human activities have put the natural biological system on overload, destroying that equilibrium. We might think of biological pollutants as chemicals which occur naturally in the environment, but create pollution in a water body by their excess. In addition to organics, nutrients, and sediment, many other pollutants are "natural" in origin, and exist throughout the environment in very small quantities. These chemicals pollute by their concentration, as introduced to the aquatic environment by man-related extraction and reprocessing. While they are derived from natural sources and significantly impact the marine ecosystem, they might be considered more as chemical pollutants. These include metal ion species (the so-called heavy metals), hydrocarbons (oil, gasoline, phenols, benzenes), and other relatively innocuous materials such as salt.

Perhaps the greatest distinction between biological and chemical pollutants is that the effects of organic excesses, sediment, and nutrients are obvious and immediate in coastal waters. Thus, while the existing record of water quality measurement for these pollutants is inadequate, their pollutional influence is well documented by diminished finfish and shellfish harvests, algae blooms, and a decrease in recreational usage of coastal waters. For the trace metals, hydrocarbons, and synthetic organics, the impacts are far more subtle, and their concentration not effectively measured at present. The available scientific record for these less obvious NPS pollutants in coastal waters is virtually nonexistent, and their presence as pollutants is more implicit by materials usage, rather than by actual measurement.

While we have failed thus far to properly measure the form of pollutant types in our coastal waters, it does not mean that we cannot act to correct the obvious degradation while at the same time planning to better measure this aquatic system. That measurement effort begins with a careful inventory and study of materials usage within the coastal drainage area, from fertilizers to gasoline. At the same time, the system itself must be properly monitored, both in terms of chemical concentrations present in water and sediments and also in terms of biological impacts, from loss of habitats to algae blooms. If the chemical form and nature of the NPS pollutant which impacts the coastal drainage is defined, the available solutions for reduction or management will become apparent. The basic rule is to establish the tolerance limits of the receiving aquatic system and live within those limits. That means that the criteria will vary, from flowing tributary to coastal estuary to barrier island. The uses of the aquatic resource, as shellfish bed, recreational area, or wildlife habitat, will also influence the priorities assigned.

Examples Of Nonpoint Pollutants

Phosphorus

The failure to adequately restore water quality in the nation's rivers, natural lake systems, manmade reservoirs, ground water aquifers and coastal waters has been a frustrating problem. While the billions of dollars which have been spent on wastewater treatment facilities has resulted in the improvement of many large inland rivers and some coastal harbors, the deterioration of lacustrine systems and coastal estuaries, in particular, has continued virtually unabated. While they are very different types of aquatic ecosystems, their role as sediment and nutrient traps for contaminants flushed from upland drainage provides a common element.

In many river basins across the country, lakes and reservoirs are uniformly undergoing a premature aging process called "cultural eutrophication." This unnatural condition is characterized by the excessive growth of algae and aquatic vegetation, and frequently results in deteriorated water quality, both within the reservoir and in downstream releases. In the case of many manmade lakes, the process of cultural eutrophication has greatly reduced, if not altogether prevented, the intended uses for which many of the reservoirs were constructed.

The cause of this pollution has been the subject of scientific study for many years, but during the 1960's there occurred a general awakening to the problem by the scientific community. The decade of the 1970's saw an intensive effort on many fronts to understand the causes and cures of eutrophication, and a library of research was conducted during that time. While the nature and cause of the condition was the subject of some difference of opinion in the early stages, most investigators eventually concurred that phosphorus was the key chemical nutrient in producing the undesired biological response in most lake systems. This agreement that "phosphorus was the key" was quickly followed by numerous studies which attempted to define the exact nature of pollutant generation, transport, and availability. Several large freshwater lakes, in particular the Lake Erie basin, became the focus of national interest and research into the problem of what came to be called "nonpoint" sources of pollution (COE, 1976; Cahill et al, 1977). Not only phosphorus, but other nutrients such as nitrogen and manmade chemical pollutants such as PCB's, which were usually associated with runoff from land, were studied in detail in the Great Lakes system.

Phosphorus serves as an excellent example of a nonpoint pollutant. This element is in common use for a beneficial purpose and is not toxic or carcinogenic. It is not generally regarded as a problem chemical. The negative effects which are experienced are the result of allowing excessive concentrations to pass directly into our surface waters. Since the natural background levels of this element are quite low in most aquatic environments, the introduction of phosphorus in abundant quantities from wastewater, agriculture, and horticulture creates an imbalance in the natural ecosystem. Of course, we could no more easily ban the use of phosphorus than fuel oil or road salt. By considering these contradictions with respect to this one element and its water quality impacts, we can better understand why the issue of nonpoint source reduction is so complex.

It has been established through exhaustive research (Mackenthun, 1965; Symons, 1969) that the waters draining into a lake or reservoir must have an average concentration of 30 ug/l or less of total phosphorus, if eutrophication is to be prevented. The influx from many drainage basins, both predominantly agricultural and mixed land uses, is frequently well above this level. More importantly, the storm-related phosphorus which is transported in association with and attached to colloidal soil particles is usually the largest single fraction of phosphorus input (Baker, et al, 1984). In the coastal drainage region of New Jersey, the same mechanisms of enrichment occur, although no specific critical concentration of phosphorus has yet been established. Since very little analysis of mass transport through estuary systems has been conducted, this study estimates that influent stormwater should not exceed 50 ug/l, although future research may prove that a lower limit is appropriate. The proposed criterion is derived from prior studies of inland drainage systems which flow into freshwater impoundments and major lacustrine environments, such as the Great Lakes.

Nitrogen

As for nitrogen, many if not most investigators conclude that it is this element which is limiting in marine environments (Ryther, 1971). In upland environments, various technologies for removal of nitrogen from wastewaters have been considered, with limited application. In general, the issue has been moved to the back burner, with the scientific community concluding that relatively little improvement in riverine water quality would result by massive programs to reduce nitrogen in wastewaters. Most freshwater systems are relatively abundant in this element, and in forms (ammonia and nitrate) which are available for biological uptake. Not only wastewaters but agricultural and industrial sources, as well as rainfall (as much as 0.75 grams per square meter in moist temperate areas), much of which is ammonia or results from nonbiological fixation in the atmosphere (Odum, 1971), contributes to the available supply. In the total ecosystem, we have increased the input of nitrogen significantly during the past several decades (Figure 24), resulting in excess fixed nitrogen flushed into the oceans.

In spite of this relative abundance, those scientists who have intensively researched the chemistry of coastal New Jersey waters have measured very low levels of available nitrogen, as compared to freshwater systems. It has been concluded that this element is critical, and regulates the primary productivity of water bodies such as Great Bay (Durand, 1980).

> "It has become clear that primary phytoplankton production is controlled by the nitrogen supply made available from a variety of sources (stream drainage, benthic regeneration, water column regeneration) coupled with the local aquatic light regime. In New Jersey coastal bays, phytoplankton primary production contributes significantly to food stocks during the warmer months of the the year. At other times, approximately from late September through spring, primary productivity rates are low, often near zero. During these times, the availability of detrital materials must account for the major part of food supply in the systems."

The concentrations of inorganic nitrogen in the marsh creeks of the New Jersey coastal bays are also reported to be generally smaller than those reported in Delaware Bay (Aurand and Daiber, 1973). As for the role of the estuaries as repositories of nutrients flushed in from uplands, Durand has reported (Figure 25):

> "Where some studies emphasize the passage of nutrients through estuaries and the role of the estuary as a sediment trap (Hobbie, et al, 1975), the passage of materials out the lower end of the estuary is frequently not given due recognition. Because of productivity within the bay, the output is mostly in organic form, either as live organisms or as soluble compounds produced by them. These organic materials may enter nutrient regeneration pathways in the surface waters of the immediate nearshore ocean area. Such regeneration is a significant contribution to nutrient cycling in the

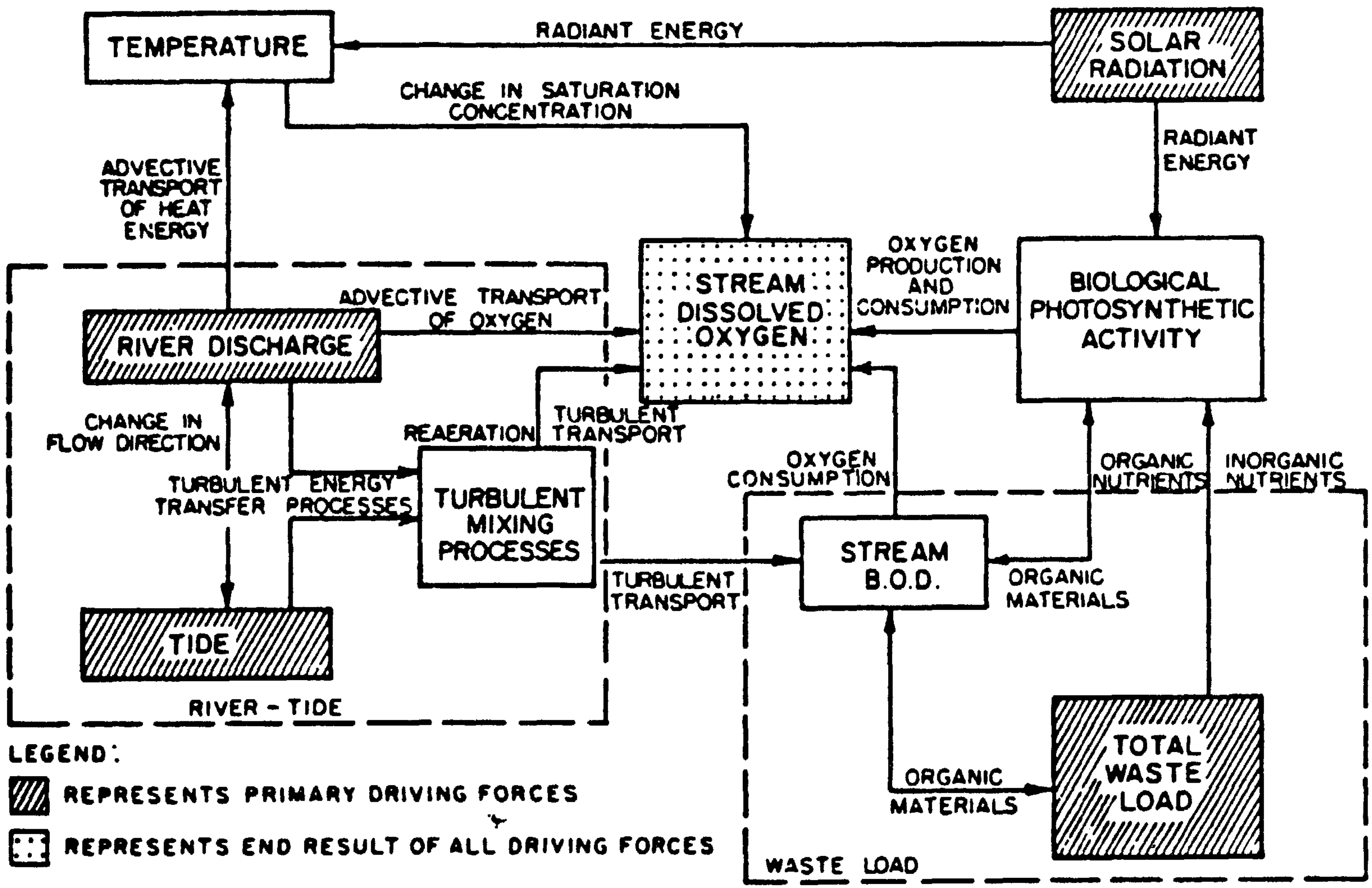


Figure 24. Factors Affecting Dissolved Oxygen in Coastal Waters (Pritchard, 1967)

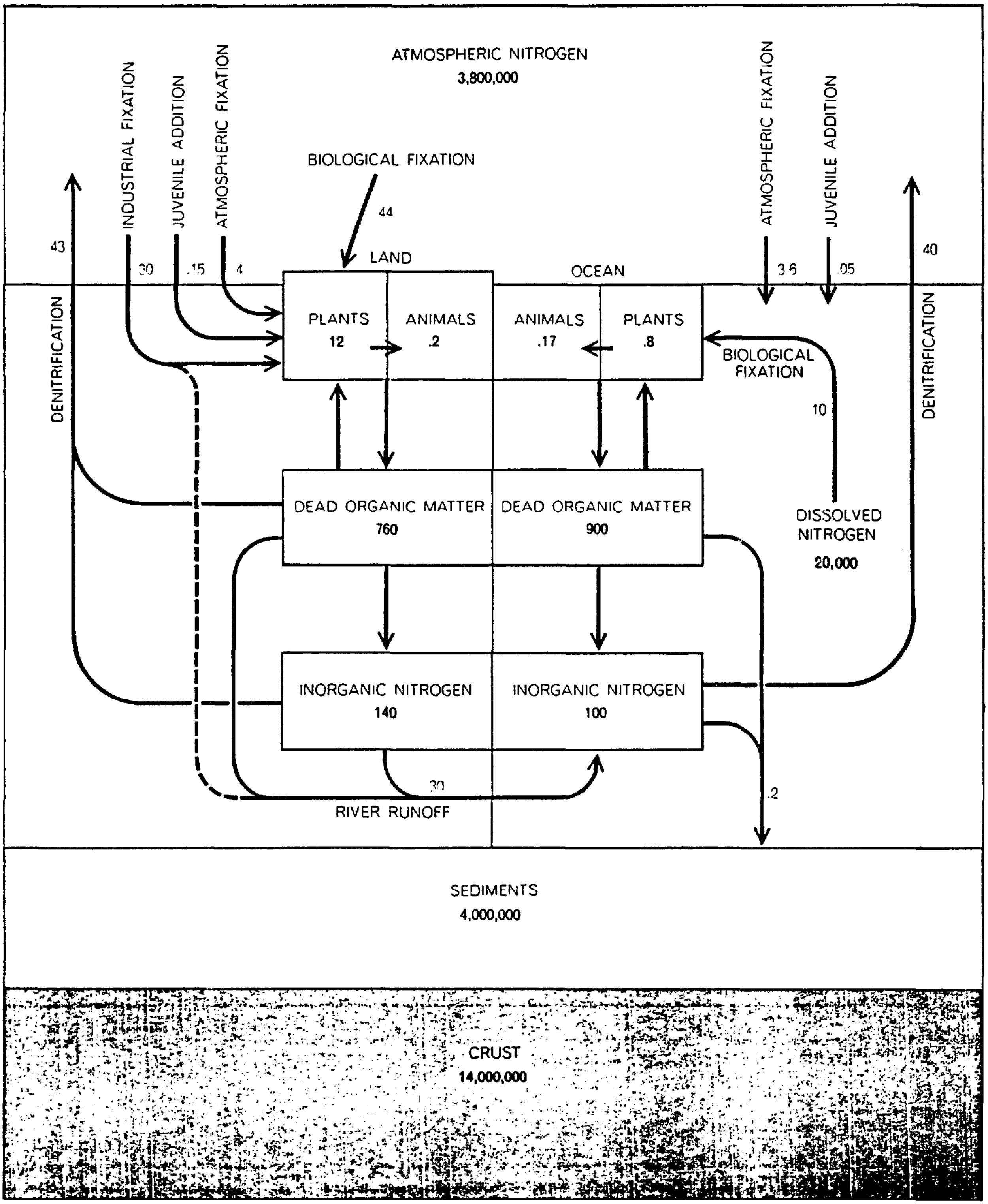


Figure 25. Nitrogen Distribution in the Ecosystem (Scientific American, 1970)

nearshore ocean surface layers, particularly in the summer months when the thermocline prevents supply of materials from the bottom layer."

Thus, we reach the conclusion that both nitrogen and phosphorus are important NPS pollutants within the coastal waters of New Jersey. All stormwater management strategies which are to be developed and applied must deal with both elements and must significantly reduce their input from land surfaces. This is independent of the potential input from atmospheric sources, which in the case of nitrogen can be substantial. Nevertheless, it would be incorrect to focus only on the phosphorus input to coastal waters, since the limiting nutrient may be nitrogen in many portions of the coastal waters and at various times of the year. Because of the unique nature of these waters and their sensitivity to enrichment, both soluble and particulate forms of these two nutrient pollutants must be removed from runoff or reduced on the landscape.

The problem of nonpoint source pollution certainly has many other dimensions beyond the issue of enrichment by nutrients, including organic loadings, petroleum hydrocarbons, heavy metals, and synthetic organics. The magnitude of these problems varies with different phases of the coastal aquatic system. Tributary freshwater rivers and lakes, brackish estuaries and embayments, and near shore coastal waters can all be impacted as contaminants pass through them. This Manual is concerned with not only the pollutant problems in estuary systems, but also with the flowing streams which drain into these estuaries, and while the prior discussion emphasizes the relative availability and utilization of the two nutrients, as they effect the rate of eutrophication, this is only one aspect of the complex aquatic system which exists in the coastal drainage.

The impact and fate of other pollutants in the environment will vary, but they will follow the same basic flow pathways as the soluble or particulate forms of these two pollutants. From a water quality management perspective, therefore, consideration of the nutrients is critical.

Oxygen Demanding Organic Matter

Other nonpoint pollutants, such as organic matter, have proven to be the critical pollutant which limits the use of some phase of the aquatic system. For example, the organic residual flushed from the land surface increases the level of bacterial decomposition in coastal waters following storms (Figure 19). How much of this organic loading may be attributable to vegetation (terrestrial and aquatic) which has resulted from enrichment is unknown, but the interrelationship of organics and bacterial levels to nutrients is direct and important in the coastal drainage. Thus, we have the direct input of organic matter from the land surface, which exerts a demand for oxygen in the decomposition process, and a secondary demand created by decomposing aquatic vegetation, stimulated by excessive nutrients. The measure of this total pollutional load of oxidizable organic matter is made by the determination of chemical oxygen demand (COD) in the water, as compared to the more traditional parameter of biochemical oxygen demand (BOD), generally associated with wastewater discharges.

In point of fact, very few measurements of COD have been performed in New Jersey coastal waters. In spite of the simple, straightforward analytical procedure used in this test, it has seen very little application as a measure of coastal water quality.

This study recommends strongly that a much better understanding of pollutional conditions in coastal waters would result if this parameter

were made a part of the ongoing data base development, and used as a measure of the organic input from stormwaters.

Bacteria

The weakness of the fecal coliform test data so common in coastal water quality inventories has been discussed in this report and elsewhere, but some measure of microbial activity is still necessary as a monitor for potential health effects. The high concentrations of bacteria measured in estuaries and nearshore waters in late summer may be attributable to decaying algae, land runoff, or the bathers themselves. Even the residual organic loading from major point source discharges, while chlorinated to kill off the microbial community present in the effluent, will stimulate a new growth of microbes to complete the decomposition process in the coastal waters. Distinguishing between these multiple sources of microorganisms, some of which may represent real and direct opportunities for disease transmission, is a difficult task, if forced to rely on only one simple and inaccurate parameter. The use of the enterococci group of organisms is a better, but not yet adequate measure for bacterial contamination and should not be done out of context. That is, the other measures of water quality must accompany this procedure, if we are to understand the causes and effects of pollution in the coastal environment. For this report, we include the generally accepted level of enterococci bacteria for contact recreation as a recommended level in stormwater runoff, recognizing that most of the BMP measures discussed in Chapter Five should be quite effective in achieving this criterion. Actual monitoring data may indicate that a higher level is appropriate, but initially a conservative approach is recommended.

Petroleum Hydrocarbons

The discussion of stormwater BMP's in Chapters Four and Five will distinguish between the quality of runoff from impervious and pervious surfaces, with a great deal of concern given to the pollutional loading from impervious surfaces such as parking lots and roadways. One of the major problems here is the significant input of petroleum hydrocarbons which are generated by motor vehicles (and to a lesser extent by heating and energy systems) which find their way into stormwater runoff. As a nonpoint source pollutant, these materials are quite specific to the runoff from paved surfaces, and a significant constituent in most urban studies. In fact, some investigators (Whipple and Hunter, 1981) have concluded that "...The most common toxic pollutant in urban runoff appears to be petroleum hydrocarbons, followed by lead, copper, cadmium, PCB's and pesticides." Related reports on stormwater quality in New Jersey have stated:

> "Hydrocarbons usually occur in concentrations of from 2 to 4 mg/l in urban runoff, mainly in particulate form, the remainder being dissolved. Although runoff from streets and parking lots has perceptible oil sheens on the surface, which are in liquid form, petroleum hydrocarbons are quickly sorbed on the particulates in runoff; so that storm sewers rarely contain hydrocarbons in liquid form unless substantial quantities have been spilled or deliberately released in the catchment area."
>
> (NJDEP, 1987)

Studies in the San Francisco Bay area (Stenstrom et al, 1984) measured concentrations of oil and grease at 4.1 mg/l in residential areas and 15.3 mg/l in parking lots. One of the major reasons for concern with the input of petroleum hydrocarbons to coastal waters is the possible toxic effects to biological communities. A recent study in the Delaware estuary (Haskin, 1987) indicated that concentrations of 1 mg/l of petroleum in water, when sorbed onto particulates, had serious adverse effects upon filter-feeding biota.

Again, as in the case of nutrients and organics, very little data actually exists on the ambient concentrations of petroleum hydrocarbons in New Jersey coastal drainage. In fact, very few measures of this NPS pollutant have been made in these waters, other than in response to specific pollution incidents, such as oil truck spills and leaking gasoline tanks. Part of the stormwater management strategy in the coastal drainage must center on the elimination of or failsafe protection of such storage and transportation elements, especially in relation to their proximity to the water's edge. While the low level stormwater drainage is an issue to be addressed by application of BMP's, the opportunity to apply such measures diminishes with development along the shoreline. Use of oil and grease separators for storm drainage from paved surfaces in coastal locations is only marginally effective. The most effective BMP's may prove to be those which eliminate the source, such as reduction of impervious surfaces and the vehicles which require them, especially on the barrier islands.

Synthetic Organic Chemicals

Other NPS chemical pollutants of great concern are those manmade or synthetic chemicals which short circuit the biochemical processing or breakdown mechanisms and either destroy organisms or threaten man. These NPS pollutants are generally more resistant to biochemical change and pass through the aquatic environment in such a way that the entire food chain is disrupted. Chemicals formulated to selectively kill undesired organisms or vegetation, to lubricate or insulate, can be taken up in the aquatic system and impact other water users, from mayflies to man. A litany of acronyms, such as PCB's and TCE, have become more than familiar to the general public during the past ten years and represent only a tiny fraction of the total list of possible problem synthetic chemicals. One recent review of our current understanding of manmade organic compounds in surface waters (Smith et al, 1988) discusses eight groups of synthetic organic chemicals (Table 17), and for each group offers data on current use, production, and properties, as well as geographic and temporal contamination trends.

For certain of these pollutants, we have learned that the acceptable limit in the environment is zero. Some of the synthetic organics which have had broad use in our society during the past 30 years must be entirely excluded or removed from the aquatic ecosystem, since they accumulate in the food chain and pose long term health threats to all organisms. From the polychlorinated biphenyls (PCB's) and the chlorinated insecticides to the polycyclic aromatic hydrocarbons (PAH's) found in oils, gasoline, bitumen, and wood preservatives, the bioconcentration factor (BCF) is a critical determinant in considering usage in the coastal drainage. Smith describes the eight groups as they might occur in materials of common use within the coastal drainage, as well as their tendency to bioconcentrate. Here the threat of the NPS pollutant is to the higher life forms which harvest the food chain, specifically man.

Metals

The presence of certain metals in stormwater discharges to coastal waters is a matter of concern. Much has been written concerning the use and concentration of metals in dredged material, sewage sludge, and chemical wastes discharged to the New York Bight (NOAA, 1979), as well as atmospheric input and land runoff. A list of selected metals of concern was developed by the New York Bight Chemical Contaminants Panel in 1976 (Kolojeski, 1976), and included antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc. The estimated consumption in the US, relative importance as marine pollutants, relative hazard based on supply and toxicity, and potential intake of metals by humans from seafood was outlined, and a final ordering of heavy metals according to hazard was presented (Table 18). As a point of departure for

TABLE 17.

SYNTHETIC ORGANIC CHEMICALS AS NPS POLLUTANTS
(Cahill and Associates, derived from Smith et al, 1988)

SYNTHETIC ORGANIC CHEMICAL GROUPS	USAGE
1. Polychlorinated biphenyls (PCB's) and Organochlorine Insecticides	Decreasing
2. Carbamate and Organophosphorus Insecticides	Increasing
3. Herbicides	Increasing
4. Phenols	Increasing
5. Halogenated aliphatic and monocyclic aromatic hydrocarbons (MAHs)	Increasing
6. Phthalate esters	Increasing
7. Polychlorinated dibenzo-p-dioxins (PCDD's, found in pest.as byprod.)	Not Manuf.
8. Polycyclic aromatic hydrocarbons (PAH's)	Increasing

FATE OF GROUP IN THE ENVIRONMENT
(Cahill and Associates derived from Moore and Ramamoorthy, 1984 and Smith et al, 1988)

GROUP	Adsorption and Partioning to Sediments	Bioaccumulation	Transformation (Photolysis, Hydrolysis, Biodegradation and Volatilization)
1.	Strong	Very Significant	Persistent
2.	Weak	No	Rapidly degrade
3.	Weak (some ex.)	Minor	Rapidly degrade
4.	Weak	Minor	Biodegradation, photolytic oxidation
5.	Weak	Minor (some ex.)	Volatilization
6.	Strong	Significant	Biodegradation
7.	Strong	Significant	Very slowly degrade
8.	Strong	Significant	Slowly biodegrade

Table 18. **Heavy Metals in the New York Bight - Hazard Ranking**

Element	Amount in New York Bight	Bio-accumulation	Acute Toxicity	Sum of Rank Scores
Antimony	1	1	2	4
Arsenic	2	2	3	7
Beryllium	1?	2	1	4
Cadmium	2	2	3	7
Chromium	2	2	3	6
Copper	2	2	2	6
Cyanide	1	1	3	3
Mercury	3	3	3	9
Nickel	2	2	1	5
Selenium	2	2	3	7
Silver	2	2	2	6
Thallium	2?	2?	3	6?
Zinc	3	3	1	6
Lead	3	3	2	7

NOTE: Question marks(?) indicate that very little information was available for determining rank. In these instances, rank was based on the best judgment of the authors after review of the existing data.

consideration of metals in coastal stormwater runoff, this table suggests that mercury, lead, arsenic, and cadmium should be of concern.

It is of interest that the current data for lead indicates a significant decrease in recent years, with the advent of unleaded gasoline in common usage (MWCOG, 1983). For this report, the virtual absence of monitoring data for these four metals in New Jersey coastal waters south of Sandy Hook suggests that they should be a part of the NPS monitoring program until a satisfactory data base can be compiled. The stormwater effluent standards are suggested from current EPA guidelines and may be revised as additional knowledge is developed.

Pollutant Transport and Depositional Mechanisms

It is well established that nonpoint pollutants move into the aquatic environment with storm water runoff, both in solution and attached to particulate material which is flushed from the land surface and transported to streams, rivers, lakes, and estuaries. There the pollutants may pass through the aquatic system, causing some degree of harm as they do, or they may reside in a stream, lake, or estuary bottom for a longer period of time. The ultimate fate of a given pollutant is a function of its chemical properties and form, but suffice it to say that regardless of the reactions and processes which take place, the flow pathway is basically the same. Thus the explanation of nonpoint source impacts and intervention methods begins with an understanding of the hydrologic regime. Defining how a watershed or river basin responds hydrologically to a given input of rainfall, and how runoff occurs, will establish the basic mechanisms of nonpoint pollutant transport.

In the drainage basins of the New Jersey coastal zone, however, all of the arguments as to mechanisms of runoff production are academic. Only two extremes exist: those portions of the watersheds which are undisturbed and, because of the sandy soil and vegetative cover, allow virtually every drop of rainfall to directly infiltrate, or those areas which have been disturbed and covered with impervious surface and produce immediate and direct runoff to surface channels and water bodies. For those pollutants which are deposited on the land surface in a particulate form or react chemically to bond with or form particles, the process of transport and deposition will be entirely dependent on which of these two surface conditions exist. In undisturbed areas of the coastal drainage, the infiltration of rainfall into the sandy sub-soil can serve as a very effective filtration process,and significantly remove any particulate pollutants from the rainfall as it passes first vertically and then laterally through the shallow groundwater system to the surface channel (Figure 7). The degree and effectiveness of this natural filtration process is dependent on the length of the sub-surface pathway, as well as the chemical properties of the soil, and so the greater the distance of pollutant deposition from surface flow system, the greater the reduction of pollutant. For those particulate pollutants which are deposited on any impervious land surface, from driveway to dock, the transport process follows the basic pattern of particle suspension with incident rainfall, transport, and deposition when the fluid velocity is reduced (as in a lake or bay).

The second group of NPS pollutants are those which are soluble in original form, or become so when washed with rainfall. The salts and petroleum hydrocarbons, the pesticides, synthetic organics and nitrogen fertilizers, and all of the various decomposition products which result from organic detritus are representative of soluble (or emulsified) pollutants. For these NPS pollutants, the process of transport and deposition is very different, and they will continue to move with the runoff through the sandy soil (for the most part) and with the direct runoff from impervious surfaces. Upon entering some phase of the aquatic system, be it stream, lake or estuary, they will be readily available for utilization by the microbial community. Some soluble chemicals will form complexes in the water and precipitate as particles to the stream or estuary bottom, entering into the sediments for a prolonged period or quickly resuspended under future runoff events, to be further deposited downgradient in the aquatic system.

Thus, we have two chemical forms of concern: soluble and particulate. We also have two types of surface conditions in the coastal drainage, permeable and impermeable, without the range of surface conditions which exist in most inland watersheds. In this complex world, the simplicity of these conditions is encouraging. All that would appear to be necessary is to prevent all direct runoff from impervious surfaces to enter sensitive water bodies, while eliminating the opportunity for soluble contaminants to be mixed with and conveyed in rainfall. The reality of land use patterns and existing drainage systems in the coastal region, however, offers countless examples of why such a simplistic answer is inadequate. Recognizing that it will be virtually impossible to implement any regulations which would address this problem in such a direct but impractical manner, we should also consider the NPS problem from a somewhat different perspective.

Critical NPS Pollutants and Stormwater Quality Criteria

With the unique hydrologic conditions of the coastal drainage in mind, and recognizing the distinction between soluble and particulate forms of NPS pollutants, one approach proposed here is to set discharge standards for those chemicals and pollutants which offer the greatest potential impact to the waters of the coastal drainage. The nutrients nitrogen and phosphorus have been discussed in some detail, and because of their importance in the environment and the transformation of forms as they pass through the estuarine system, receive special emphasis in this Manual. In a sense, the respective form is a minor consideration when evaluating the total mass loading of these two pollutants into coastal waters, and so they are listed in total elemental form, on our short list of critical NPS pollutants in the New Jersey coastal drainage (Table 19).

Of equal importance are the various forms of organic material which are lumped together in the water quality measurement of chemical oxygen demand (COD) and which comprise the food source for microbes. This simple test of the total chemically oxidizable content of stormwater provides an excellent measure of NPS pollutant input and is included in Table 19. In many ways, it is the best yardstick for quantifying the organic loading to the coastal waters.

The inclusion in Table 19 of a microbiological parameter is intended to begin the correlation of stormwater runoff chemistry with the existing water quality record of fecal coliforms discussed earlier. The parameter recommended is the enterococci test, with the EPA standard used for stormwater discharge limits. This will allow the evaluation of runoff from parking lots and lawn areas, as distinguished from storm sewers which may include illegal wastewater flows. The standard may change as a better water quality data base is developed, because we are not currently capable of making that distinction.

The total suspended solids parameter is included as a significant pollutant for two reasons. Upon entering the estuary (or flowing directly into bay or coastal waters) the particulate material, most of which is suspended inorganic sediment, can settle and cover the benthic habitat. The sediment also serves as a transport vehicle for phosphorus, heavy metals, and synthetic organics. Thus, this pollutant has both a direct and an indirect impact on the coastal ecosystems. One might argue that the settling of sediment in estuaries is a perfectly natural process, and in point of fact, that is true. As in the case of nutrients, it is an excess of the material which degrades the aquatic environment and mandates that it be controlled in our stormwater discharges.

TABLE 19.

NPS POLLUTANTS IN THE NEW JERSEY COASTAL ZONE STORMWATER MANAGEMENT CRITERIA (mg/l)

(Cahill and Associates, 1988)

POLLUTANT	STORMWATER CRITERIA (Recommended)	PRESENT LEVELS
Total Phosphorus	0.050	0.030 - 1.00
Total Nitrogen	0.700	0.300 - 2.00
COD	10	5 - 150
Total Suspended Solids	20	10 - 500
Enterococci	35 CFU/100 ml	Unknown
Petroleum Hydrocarbons	1	2 - 15
Metals (1)		
Lead	0.020	0.010 - 0.700
Mercury	0.001	Unknown
Arsenic	0.010	"
Cadmium	0.010	"
Synthetic Organics		
MAH's	0.100 (2)	"
PAH's	0.100	"

(1) See discussion of heavy metals criteria in text.

(2) Several of the halogenated and monocyclic aromatic hydrocarbons included in this grouping have specific standards in drinking water, including trichloroethylene (0.005), carbon tetrachloride (0.005), vinyl chloride (0.002), dichloroethane (0.005) and benzene (0.005).

The inclusion of petroleum hydrocarbons, as well as the four heavy metals which have the greatest potential risk to the marine environment, is essential in light of present knowledge. The stormwater effluent criteria for heavy metals are somewhat subjective, and may also be revised as better monitoring data is developed. They represent a mix of Federal guidelines or recommended criteria for contact recreation waters and protection of saltwater organisms. For example, the current lead criterion in drinking water for human health is 20 ug/l (reduced from 50 ug/l in the Safe Drinking Water Act of 1974). Guidelines for acute toxicity to aquatic life (668 ug/l) and chronic toxicity to saltwater organisms (25 ug/l) are different (Sitting, 1981). Thus, the recommended criterion of 20 ug/l may seem overly conservative; however, the basic source of lead in stormwaters, leaded gasoline, has been dramatically reduced in recent years, and stormwater runoff from coastal impervious surfaces should not approach the concentrations of previous studies, in the range of 100 to 700 ug/l (OWML, 1983). Given the direct ingestion of coastal waters by humans, it does not seem unreasonable to require such a criterion. Mercury compounds, on the other hand, are found as timber preservatives, disinfectants, herbicides and other uses which may take place in the coastal drainage, and, as methylmercury, are quite toxic to both humans and aquatic life, with a recommended ambient value of 0.025 ug/l for saltwater organism, a chronic value of 2.8 ug/l, and a human health value of 0.2 ug/l (Sitting, 1981). Thus, the recommended criterion of 1ug/l may seem excessive. If future monitoring indicates a consistent presence of mercury forms in coastal drainage, this criterion may need to be lowered, but for now it may be considered a concentration level of concern. For arsenic, the concentration with potential impact on aquatic organisms (440 ug/l) is also much higher than human health concern levels (0.02 ug/l), but lower than drinking water standards.

Finally, the synthetic organics are included by the measurement of two of the groups discussed in Table 17, the PAH's (Group 8) and the MAH's (Group 5). These groups are the most likely and most significant organics to be anticipated in the coastal waters. They are representative of the manmade organic chemicals which might occur in coastal stormwater, even though these synthetic organics are virtually unmeasured in coastal waters except for a few special studies in the northern Bight area. They are included not because we have identified a problem, but rather to determine if one exists. Table 20 lists the representative synthetic organic chemicals to be included in the NJDEP coastal monitoring program. Again, the recommended criteria reflect a mix of considerations and data. Some of the organics listed were included in the Proposed Primary Drinking Water Standards by EPA (40 CFR Pt. 141, June 12, 1984) with recommended maximum contaminant levels (MCL's) of zero, and others have now been added to the drinking water standards applicable as of Dec. 31, 1988, with specific values in the range of a few parts per billion. Rather than including such specific concentrations in this Manual for stormwater runoff criteria, it seems more appropriate to include a larger group of related compounds and set a criterion for the group, which may in fact be higher than the desired level for any specific chemical. When their collective presence in coastal drainage is better understood, NJDEP may wish to establish specific values for selected organics.

TABLE 20.

SYNTHETIC ORGANIC CHEMICALS OF INTEREST IN THE ATLANTIC COASTAL DRAINAGE

(Cahill and Associates, 1988)

Halogenated Aliphatic and Monocyclic Aromatic Hydrocarbons

Chloromethane	
Dichloromethane	Benzene
Chloroform	Toluene
Carbon Tetrachloride	Xylene
1,2-Dichloroethane	Chlorobenzene
1,1,1-Trichloroethane	1,2-Dichlorobenzene
1,1,2,2-Tetrachloroethane	1, 4-Dichlorobenzene
1,2-Dibromoethane	2,6-Dinitrotoulene
Ethylene Dibromide	1,2,4-Trichlorobenzene
Vinyl Chloride	Ethyl Benzene
Trichloroethyene	Nitrobenzene
1,1,2,2-Tetrachloroethyene	Florobenzene
Bromoform	Bromobenzene
1,2-Dichloropropane	Iodobenzene
Trichlorofluoromethane	

Polycyclic Aromatic Hydrocarbons

Anthracene
Benzo(a)anthracene
Benzo(b,j,k)fluoranthene
Benzo(g,h,i)perylene
Benzo(a)pyrene
Chrysene
Coronene
Dibenz(a,h)anthracene
Fluoranthene
Fluorene
Indeno(1,2,3-cd)pyrene
Phenanthrene
2-Chlorophenanthrene
2-Methylphenanthrene
Pyrene
Methylpyrene
Perylene
Napthalene

Note: PAH's originate from both natural and anthropogenic sources. However, it is believed (Cossa et al, 1983) that their occurrence in aquatic systems is due primarily to anthropogenic inputs.

CHAPTER 4.

NPS POLLUTION CONTROL TECHNOLOGY IN THE ATLANTIC COASTAL DRAINAGE

CHAPTER 4.

NONPOINT SOURCE POLLUTION CONTROL TECHNOLOGY IN ATLANTIC COASTAL DRAINAGE

Introduction

The recognition that significant amounts of pollutants are discharged to coastal waters of New Jersey from land runoff argues for the development of methods or techniques by which to prevent this discharge, or reduce the concentrations of contaminants in the resultant stormwater. Unlike the technology which has been developed to treat the wastewaters collected from our municipalities and industries (i.e., point sources), the use of chemical or biochemical techniques in closely controlled systems of unit operations has little applicability in this nonpoint source context. As in the case of traditional stormwater management techniques, much of our initial technology has evolved from the agricultural community, where the problem of sediment in runoff was a concern long before the issues of other pollutants were even recognized. Methods to reduce the loss of sediment from cultivated land, or prevent its discharge into adjacent channels and waterways, were developed and applied. In time, these various methods for agricultural land management were labeled "Best Management Practices" (BMP's). As the issue of NPS pollution was recognized as much more than just a problem from cultivated land, the same basic BMP's were considered for application in the suburban and urban setting. In addition, the structural elements of our existing stormwater collection systems were evaluated to determine if they could be modified to function in a fashion which not only conveyed runoff, but removed pollutants as well. Thus we have developed a mixed bag of methods and measures which are considered to be BMP's for stormwater quantity and quality management, most of which are based on direct physical intervention in the stormwater flow, are structural in nature, and usually are applied on a site-specific basis.

Traditionally, BMP's have been thought of as site-specific structural measures to be incorporated into site drainage system design. But the possible BMP's which could be developed and applied in the Atlantic coastal drainage of New Jersey theoretically could be much more far-reaching and diverse in nature. Beyond direct physical intervention in stormwater runoff at a specific site, these potential BMP's could be areawide in scale, extending well beyond any particular site boundary and incorporating non-structural planning techniques, such as development density reduction and conceivably even outright development prohibition itself. Non-structural BMP's tend to be preventive in nature and therefore are the preferable strategy from a technical perspective. Unfortunately, because such preventive strategies tend to require sometimes dramatic changes in institutional arrangements, such as involving the State directly in the direct municipal regulation and use of land, these strategies are sometimes extremely difficult, if not impossible, to implement. Political resistance, which certainly would accompany such an expanded regulatory program on the part of NJDEP, could be insurmountable.

Alternatively, non-structural approaches could incorporate measures such as deed restrictions required as part of a coastal permit. These deed restrictions or restrictive covenants could limit site disturbance and maintenance, including application of fertilizers, pesticides and herbicides, and could stipulate that carefully controlled and improved housekeeping practices must be employed on an individual, if not community-wide, basis. Although this Manual is intended to augment the program of the Division of Coastal Resources by detailing permit or development-specific BMP's and by establishing a scheme for BMP selection and application, which we do below and in the following section, it should be recognized that non-structural BMP's, however difficult to implement, may also have to be considered more seriously if truly preventive water quality management programs are to be put in place.

Land Use Management and Source Control: Non-Structural Approaches

Before further detailing BMP's and developing a process for BMP selection, additional discussion of the more theoretically ideal and preventive non-structural management techniques is in order. When we consider the assortment of pollutants which degrade the Atlantic coastal drainage, our first thought is to reduce or eliminate the opportunity for those contaminants to enter these waters with the runoff from our landscape. The most straightforward pollution control "technology" is not a technology at all, but rather the non-structural technique of modifying and/or managing our use of the land so that these nonpoint pollutants are either not generated or are reduced in quantity. Those land uses which have a greater potential for pollutant production ideally should be eliminated or at least reduced in extent. Rather than devising schemes of structural and biological systems which remove these NPS pollutants from runoff as an afterthought, the sources of pollution ideally should be eliminated or controlled. Use of these various chemicals on the land surface should be reduced.

Such a strategy, if applied comprehensively and scrupulously, could translate into outright prohibition of new development throughout Atlantic coastal drainage areas. Such actions would have overwhelming political, economic, and social implications. Quite simply, while some would argue that a "no growth" policy warrants serious consideration, such direct intervention would go well beyond the legal and administrative mandate of the Division of Coastal Resources. However much State officials charged with maintaining water quality might want to restrict growth, each local municipality regulates the use of land, adopts zoning ordinances, encourages and induces growth by infrastructure development and other means, and plans for its own future, independent of its relative location within the Atlantic coastal drainage. This pattern will continue for the foreseeable future. The coastal permitting program, including this Manual, must carefully acknowledge and be compatible with this existing land use regulatory system with all of its deficiencies, at least in the short run, if any water quality improvements are to occur.

That is not to say that the State should not intervene in this land use management process over the longer run in a more significant way. As in the case of the Pinelands, special legislative action may be necessary to limit the use of land as it affects coastal water resources, especially where local ordinances act contrary to that goal, or are not in compliance with State criteria. Furthermore, the coastal program even as it currently is defined attempts to affect land development through its growth rating system. In practice, however, the maximum percentage impervious ratings which drive the system appear to be so high that the State guidelines--and they are more guidelines than regulations per se--rarely if ever serve to reduce development densities below that which is permitted on the local level. In many cases it appears as though local density restrictions are more stringent than the State guidelines.

How then are we to intervene? The question is not easily answered. Consider, for example, the two nutrients, nitrogen and phosphorus. As discussed earlier, it is the use of these elements as fertilizers which comprises the single greatest anthropogenic source of pollution in the coastal drainage system, with the exclusion of domestic wastewaters. But can we eliminate the use of these chemicals (as well as the associated pesticides and herbicides which accompany them) from the coastal drainage? Must we absolutely prohibit the new land development which gives rise to these pollutant loadings in the first place, or can we alter the way we develop land in order to avoid the application of these chemicals which are degrading our coastal waters? Traditionally, as we have occupied the coastal drainage in ever increasing numbers, we have attempted to replicate or transplant the environments with which we are both familiar and comfortable. This includes the development of green lawns, manicured fairways, and carefully landscaped communities where there previously had been only scrub brush and pitch pines on a relatively thin surface soil mantle over sand. As in most ecological transformations, our technology has supplanted the existing vegetated landscape and transformed it into a pleasant suburban setting with which we are familiar. Can we reasonably expect to change these customs and habits?

Another reality that must be addressed is the fact that the economic base of coastal drainage communities has been undergoing dramatic change. As the nation ages, a proliferation of retirement communities has occurred and can be expected to continue, generating considerable new development on both barrier island areas and increasingly throughout mainland areas. This development is year-round and creates demand for the full array of support services and land uses. Furthermore, we have witnessed development and expansion of the gambling industry in South Jersey, with its attendant ripple effects on both neighboring barrier islands and mainland area communities. Other industries have sought out coastal locations as well. To the north, the resurgence of the New York metropolitan area has meant land development and redevelopment beyond the expectations of many--ranging from new densely developed residential sites on the remaining vacant sites in Middlesex County communities, often with a host of environmental constraints, to major redevelopment projects along the Hudson River across from Manhattan, to high-rise office complexes at expressway interchanges--thousands of new jobs, thousands of new people! In short, what was once a rather uncivilized summer vacationland for city dwellers, with its dense and compact wooden boardwalks and strings of hotels and summer cottages, has become a permanent community for over 1.5 million people. This growth is expected to continue into the future. These ranks are swelled still further by the summer influx of tourists who come in ever greater numbers each year (at least until recently). These summer residents expect far more in the way of amenities than their grandparents. These expectations range from a boat by the water's edge to a nearby mall, fully stocked with food, furniture, and fertilizer. All of these comforts and amenities pose potential nonpoint water quality problems to varying degrees.

Therefore, we conclude that not only has the amount of new development increased dramatically within Atlantic coastal drainage, but the type of development is changing as well. These changes make the questions of restricting new development or making it happen in different ways that much more difficult. Given the literally billions of dollars of new land development at stake, does it make any sense whatsoever to consider strategies which prohibit this development at this point? Even if a political mandate could be generated for new far-reaching legislation exacting such controls on the future use of land, would the full economic and social costs of interfering with the "highest and best" use of the land be excessively high? Isn't there some technical alternative to maintaining environmental values without incurring such tremendously high social and economic costs?

Given the ramifications of a no growth policy, would it not be possible to develop without creating these problems--to develop correctly in accord with carefully established performance standards? Can new dwelling units in the retirement communities of Dover Township be constructed and marketed, for example, without large expanses of lawn and maintained areas, preserving native vegetation and eliminating the opportunity for chemical applications? In terms of existing development, would it be possible to convert the lawns of Longport to sand and gravel or native vegetation requiring no chemical application with any degree of success? Some choices still remain. But the collective response to these questions must be positive.

Certainly it may be possible to treat nonpoint-laden stormwater in some manner through combinations of on-site BMP's, but the first and most direct solutions should be preventive in nature. We must realize that much of the nitrogen and phosphorus applied to maintain the new coastal landscape pollutes the very waters which make the shore such a desirable environment in the first place. Not only nutrients, but the organic residual from new coastal drainage development is rapidly degrading coastal water quality. We must translate this water quality understanding into effective nonpoint source management programs as quickly as possible, always striving to attack the problem as close to the source as possible. Without imposition of these special performance controls, we are left with a bleak prognosis. As discussed in earlier sections, the proliferation of growth and development will continue within coastal drainage and nonpoint source loadings will increase directly above and beyond current levels.

> **In summary, more macro or areawide planning-type BMP's, however tempting and effective their promise, however close to the source and ideally preventive in nature they might be, can be expected to create innumerable regulatory battles with the large number of counties and municipalities comprising the Atlantic coastal drainage. Therefore, it is inappropriate to dwell on land management strategies insofar as the Division of Coastal Resources and this Manual are concerned. For the foreseeable future, Coastal Resources simply does not have the power to dictate what exactly happens within the Atlantic coastal drainage area--to dictate land use. BMP recommendations in this Manual, as a consequence, should not involve such macro-planning strategies, however desirable and effective they might be. Alternatively, however, the coastal program can affect how new land uses will be developed through requiring new developments to incorporate appropriate site-specific BMP's. These BMP's are presented in the next section. Although some of these BMP's in a strict sense may not prevent the generation of nonpoint source pollution, these techniques are designed at minimum to manage pollutants as close to the source as possible, such that adverse effects are adequately managed, if not eliminated.**

BMP Design Criteria Considerations

Before developing shopping lists of NPS measures and detailed descriptions of specific structural measures which are applicable to the Atlantic coastal drainage of New Jersey, it is appropriate to summarize a few basic concepts which will guide our analysis and selection of BMP techniques. The pollution control measures developed to deal with the NPS problem here and anywhere should reflect several basic planning standards or design criteria. They should:

1. Prevent or minimize the OPPORTUNITY for pollutant input

The pollutants which move with and as a part of the hydrologic cycle, transported through the aquatic system during stormwater runoff, can be reduced or eliminated in several ways. First, we can reduce the opportunity for these pollutants to become entrained in the runoff flow from land surface to stream. This translates into several specific concepts. For example, in the extreme, potential for generation of nonpoint pollutants can be eliminated through prohibition of new development. A less extreme position would be to reduce development density through modification of zoning and other municipal growth management ordinances. Imposing deed restrictions which prohibit application of fertilizers, herbicides, pesticides, and any other chemicals on the site would be another technique. Opportunity may also mean changing the way we occupy the land surface, from the types of dwelling units and commercial structures we build, to where and how we build them. Redesigning our landscapes (or not designing them at all) in a manner which requires far less nutrient application for maintenance, locating sources such as gasoline and oil tanks in secure sites, and changing the types of paints and chemicals used in boat maintenance are all examples of reducing the opportunity for NPS pollutants to drain into Atlantic coastal drainage, thereby reducing or eliminating the pollutant before it is incorporated into runoff.

In a sense, this question of reducing NPS pollutant opportunity through reduction of development densities has already been considered in the coastal permitting process, although with debatable effectiveness. Based on actual experience, integration of the coastal growth rating system into the coastal permitting program has had little, if any, nonpoint source water quality effectiveness thus far, given the very generous maximum impervious cover limits allowed in many areas. These issues of growth management in the Atlantic coastal drainage are certainly important and are discussed in greater detail below. Because of the difficulties in implementing any of these growth limiting measures, however, this Manual focuses not on the question of whether or not development should take place, but rather on how development should occur. Within that context, it certainly is appropriate to consider measures which restrict certain portions of a development parcel by deed restriction or other method, in order to reduce the opportunity for pollutant production.

Secondly, minimizing the proximity of pollutant disposal or storage (from stored industrial intermediate chemicals to trash dumpsters) to a surface stream or drainageway is another important concept in minimizing opportunity for nonpoint source pollutant generation. The example of the debris-laden urban stream channel conveying the residual runoff from carwashs and cleaners, factories and fast food stores as it drains the back alleys of Atlantic City or Toms River is one that we can all recognize. Stream channels must not be allowed to become open sewers. The natural drainage system itself must be preserved. This same reasoning would lead us to prevent cultivation of a farm field across drainage swales and ditches, in an effort to gain the use of every last acre for production. New residential development, which bulldozes over the small drainage channel in the headwaters area of a stream and replaces it with a corrugated metal pipe to allow the development of a few more lots, makes the same fundamental error--<u>failure to preserve the natural drainage system, including, but certainly not limited to, all mapped floodplains.</u> The natural drainage channels which cross the landscape are not to be treated as removable obstacles or convenient sewers. The protection of these drainage system elements must be a basic approach to prevention of nonpoint source pollution. All potential sources of nonpoint pollution, including agriculture uses, new suburban development, septic systems, landfills, gas station tanks, and any other activity which might generate substantial quantities of pollutants, must be situated away from the stream pathway and existing drainageways.

In this sense, the natural vegetative buffer which surrounds a stream or drainage channel, including wetlands, has always provided a biochemical filtration and pollutant removal system for all drainage networks. Preservation of the natural drainage system also acts to promote recharge and reduce the actual quantity of stormwater flowing from the site, further retarding the rate of runoff. This quantitative reduction also minimizes the erosive energy of the stormwater event and the damages which otherwise would result. Thus, destruction of this natural drainage system significantly increases the opportunity for NPS pollutants to enter the surface flow system directly. One of the management measures discussed in the following section emphasizes this concept of reducing NPS pollution by reducing the proximity of pollutant sources and activities to the stream system through the use of a natural buffer between pollutant source and waterway. Such measures are common sense and have been proposed previously through agricultural guidelines or land use planning concepts. In this context the measures are grouped together by their common element--the creation of a drainage network buffer zone extending across all land uses, zoning districts, and ownership parcels. This idea has been proposed in the past by numerous watershed organizations for many good reasons, not the least of which are the aesthetic and environmental benefits of wooded stream valleys. In terms of water quality, natural stream corridors with buffer zones would also appear to be one of the most effective measures to reduce stream pollution from nonpoint sources.

Carrying this concept of preservation of natural systems a critical step further, we recommend application of what we call here "minimum disturbance/minimum maintenance" landscaping for Atlantic coastal drainage developments. In minimum disturbance/minimum maintenance landscaping, not only are virtually all natural drainageway features left undisturbed, but the bulk of the site or lot area remains uncleared and undisturbed during construction and during the life of the land use. A building or site disturbance envelop is carefully delineated, encompassing only that area which must be disturbed to locate and construct the structure or use. To the extent possible, areas which must be disturbed are then revegetated with native species requiring no or minimal maintenance. This technique emerges as one of the most effective BMP's available for application in the coastal permitting program. No other technique within the purview of NJDEP's legislated mission so effectively removes the opportunity for pollutant introduction into coastal waters, is both non-structural and preventive in its basic nature, and yet does not require major State involvement in municipal land use regulation. At first glance, such a practice seems rather revolutionary from a landscape perspective--from the user's perspective. But, as several project examples such as the Bald Head Island complex and the tremendously successful Woodlands development near Houston demonstrate, such innovative techniques can be accepted by the public, by the market, and by the building industry. In fact, such techniques can be aesthetically pleasing and become market enhancement factors. Certainly the concept of minimizing, if not eliminating landscape maintenance should be highly desirable in terms of seasonal vacation use.

2. Reduce or eliminate the MOBILITY of pollutant transport

As we consider how and why NPS pollutants move into the aquatic system, available scientific research indicates that the chemical and physical mobility of various pollutants is a critical factor in their potential impact. We have learned, for example, that phosphorus is transported into and through the stream system attached to fine soil particles, or colloids. The process of fertilization results in a loose bonding of the chemical forms, usually as ortho-, meta-, or polyphosphates, to the fraction of very small soil particles. This bonding is easily broken when the particles settle out in a stream pool or lake. Biological uptake is rapid. In fact, very little of the phosphorus in transport through a stream system during runoff is in soluble form. Phosphorus usually is associated with particulate matter or is in organic form.

The solution to this mobility problem again is quite obvious. If you can reduce sediment production and prevent stream loadings from becoming a problem, then phosphorus loadings can be reduced as well. The practical application of this concept is not quite so simple, however, as the existing soil erosion technology is most efficient in collecting the larger, more settleable soil fraction. The colloidal particles (with phosphorus molecules loosely bound) can remain in suspension and are released from outlet control structures such as detention basins as waters drain. The prevention of sediment pollution is, of course, a real benefit in itself, as the heavier sediments otherwise would be carried into the stream system, would cover the stream bottom, and then would smother the benthic organisms which are so important in biochemical processes for a healthy stream. Thus, the techniques emphasized in this Manual will focus on modified methods of erosion control which accomplish a greater degree of sediment containment than has previously been proposed for conservation purposes (as discussed in earlier sections, NJDEP's new stormwater program focuses on dual-purpose detention basins which provide this added control for particulate removal).

For soluble pollutants such as nitrogen, some pesticides, and others, the issue of mobility centers on containing the land areas where such materials are applied, if indeed they must be used at all. In residential landscapes, this means containment of all plantings which are maintained artificially or chemically; the same approach is true for commercial and institutional settings. In a sense, we are confining these NPS pollutants to land areas which may be exposed to rainfall, but where the pollutants generated are not mobilized, but contained and where pollutants are not allowed to flow into surface and groundwaters.

For a certain group of synthetic organic chemicals (halogenated aliphatic and monocyclic aromatic hydrocarbons or MAH's), best known by the solvent trichloroethylene (TCE) and the widely used benzene, the issue of mobility is critical. These manmade pollutants, several of which have been identified as chemical carcinogens, move with runoff through the soil and underground aquifers without any significant interaction. They appear to remain in solution with the groundwater, which, of course, is devoid of any oxygen a few feet below the surface. These chemicals volatilize quickly when aerated in a surface water body. The primary fate of most MAH's in surface water systems is volatilization followed by photolytic degradation in the atmosphere. The observed contamination thus far has occurred largely with respect to ground water supplies, but the incredible mobility of these NPS pollutants is of deep concern to water quality scientists. Because of the large quantities of halogenated aliphatic compounds and MAH's produced in this country, the compounds have been detected in many contexts, ranging from the oysters of Lake Pontchartrain to the sediments of Lake Ontario. The only effective solution, in addition to discontinued use of the chemicals, is to assure that any disposal practice requires solidification with other chemicals in a stable matrix.

In the case of these and other synthetic organic NPS pollutants, natural biochemical processes which breakdown the chemical in the soil are totally ineffective. In fact, levels of these chemicals are better reduced by a well aerated surface water body. Therefore, the BMP's which keep these contaminants from entering the sub-surface, such as wet basins and wetlands, will both reduce mobility and allow for volatilization. For this reason, runoff from certain surfaces and under certain conditions is better managed on the surface than by fast-acting underground recharge systems.

3. Allow natural BIODEGRADABILITY to reduce the pollutants in transit

For those pollutants which require biochemical processing to render them harmless to the environment, the use of natural filtering systems, such as the soil mantle or special vegetation, can be very effective. The positive role of the surface vegetative cover and even a reasonably shallow soil mantle cannot be overemphasized. Here, the mobility of many soluble pollutants can be reduced through the interaction of natural organisms and physical-chemical reactions, such as cation exchange. For those NPS pollutants which lend themselves to this natural regeneration process and in the appropriate environmental setting, the passage of storm runoff flows over and through the proper balance of vegetation and soil can be an effective treatment process. The important distinction is that the pollutants conveyed must not be toxic to the system, or its effectiveness will be greatly reduced.

The concept of biodegradability is one that carries over from the wastewater treatment processes (i.e., point sources) which have been used effectively to treat the organic wastes of our communities. Some observers might argue that the flushing of pollutants from the land surface and their subsequent breakdown in the course of transport through the stream system is a natural process. In a sense, this is correct. Problems are created when the system is overloaded, or when pollutants are introduced which cannot be processed and which accumulate in the system with harmful effects. "Heavy" metals are good examples of such pollutants, with New Jersey's waterways bordering the New York area being probably the country's best (or worst) example. If stormwater containing heavy metals is not discharged directly into surface waters, but allowed to infiltrate into the soil mantle with certain minimal performance characteristics, metals will be bound to soil particles and will not leach into the groundwater system or flow out into coastal waters through groundwater seepage. Unfortunately, scientific documentation quantifying soil properties and performance in pollutant removal is sparse, and concern remains that certain BMP systems such as porous pavement or other infiltration techniques which facilitate removal of metals into the sub-surface soils could create future contamination problems. Exactly what amount (thickness) of what types of soils are adequate to remove what types of pollutants in what quantities over what periods of time? These are important research questions which need to be addressed by NJDEP and relevant research institutions as soon as possible.

Because much of the pollutant load conveyed with stormwater runoff eventually accumulates in particular locations, or "sinks", the nature of these sinks and the biological communities which may be supported or served by these sinks is a prime consideration. That is, impacts will vary depending on the aquatic system in which NPS pollutants accumulate. Pollutant accumulation can also further effect biodegradability. For these reasons, the distinction between riverine, lacustrine, and estuarine ecosystems is important in selecting those management practices which are best suited for application in these varying environments. Rivers have greater natural assimilative capacity and less sensitivity to enrichment than either lakes or estuary systems. As experience has demonstrated, however, the apparent lower levels of NPS pollutants in river systems can be misleading. Dilution of runoff and NPS pollutant levels suggest that the problem has been eliminated, but as the Great Lakes have demonstrated, these NPS pollutants will accumulate over time in downriver locations. In the case of New Jersey, the accumulation is in the bottom sediments of the estuaries and back bays or embayments, where the decomposition process may significantly reduce dissolved oxygen in the overlying water during the summer months and/or increase microbial levels. In a sense, the basic approach to this BMP design criterion is to confine such biochemical degradation to basins or artificial wetlands which can be managed (and if necessary aerated, harvested, or treated), rather than transferring this burden to the coastal water system.

4. Provide INTERVENTION in the system by structural or biological systems

To varying degrees, all of the measures which are described in the following sections represent some type of direct physical intervention in stormwater management, with subsequent reduction or removal of NPS pollutants. These measures deal with NPS pollutants by applying the previously discussed design criteria, as appropriate: reducing opportunity, decreasing mobility, and/or increasing biodegradability in any given situation. This is not to say that non-structural methods do not reflect the concept of intervention; some of those methods indirectly intervene in the pollutant production process, the pollutant disposal process, and the pollutant transport process. The reduction of fertilizer, herbicide, and pesticide use and application rates, for example, and even the reduction in manufacturing of certain chemicals, are possible methods of direct intervention in the NPS input to coastal waters. Requirements for storage and the removal and redisposal of waste materials from both active residential and commercial sites as well as old dumps and industrial sites is also such an approach.

However, Chapter Five primarily concerns a variety of structural BMP's which deal with the physical removal of pollutants incorporated in runoff by intervention. These structural BMP's usually represent the most expensive (though in some cases, the only) solution available. All of these BMP's directly intervene in the pollutant transport process and have been given the greatest attention in many other studies of NPS pollution (Schueler, 1987). Actually, these BMP's represent measures of last resort.

Given the constraints of the existing coastal permitting program managed by the Division of Coastal Resources, this Manual necessarily reflects a traditional focus on these structural site-specific BMP's (with a very important exception being in the area of vegetative BMP's). Most non-structural BMP's, however tempting their technical and cost-effectiveness might be, unfortunately extend beyond specific site boundaries and typically would require significant modifications and additions to New Jersey statutes and regulations. Such changes are necessarily controversial and subject to all sorts of political forces. At best, considerable time would be required for successful implementation. Therefore, we have opted to focus on measures--site-specific BMP's--which can be implemented in the near term by NJDEP staff in the established permit program work.

Given these four basic design criteria for BMP's which a site planner, landscape architect, or engineer should consider in the site design process for all new facilities in the coastal drainage (as well as all existing sites), it is appropriate to evaluate how the various land management or non-structural measures as well as the structural measures, or BMP's, might be reflected in these criteria. Table 21 shows the criteria and considers the set of BMP's to be discussed in the following Chapter Five.

A Methodology for Selecting Best Management Practices in New Jersey's Atlantic Coastal Drainage

It is obvious that the array of factors relevant to nonpoint source management in coastal waters is extremely complex, reflecting the broad variability of coastal ecosystems, differences in land development projects, and varying applicability of regulatory programs. Although some solutions will require legislative action and long term changes in behavior patterns, the focus in this Manual is to devise an immediately workable system for BMP selection by those involved in reviewing coastal permits at the Division of Coastal Resources. Any method must take full account of the importance of workability and simplicity in this process, although modifications can be made as the program is applied in the future. In addition, there are work items which NJDEP should undertake as soon as possible, in order to make the program more refined and resolve some of the considerable informational needs which jeopardize the program's potential effectiveness.

This program of BMP selection is to be applied within the existing coastal permitting jurisdiction. In no way, however, do we want to minimize the importance of our earlier recommendations which advocated jursidictional expansion (geographically and otherwise) of the coastal permitting program. This new BMP program should be applied in a significantly expanded geographical jurisdiction, including all of the coastal drainage. The new BMP program also should be applied to all types and sizes of new development, not excluding the smaller residential and nonresidential projects as is currently the case within the CAFRA zone and elsewhere. From a nonpoint source water quality perspective, the Division of Coastal Resources should also advocate the overall reduction in development densities as much as possible. Ideally, outright development prohibitions would serve water quality to the maximum, though obviously prohibition of all new development within this large zone is totally unrealistic and an extreme position at this point. Practically speaking, such prohibitions would most certainly be interpreted as economic takings by the courts and would translate into vast payments to affected property owners far in excess of State budget capability. Furthermore, from a "highest and best" land use perspective, it is not at all clear that broad development prohibitions in the coastal drainage constitute the most desirable land use option. This type of planning approach is somewhat more macro in focus and frequently can be expected to transcend any one particular permit application or development project. Thus, the BMP selection process is prefaced with a specific recommendation:

> **NJDEP's Division of Coastal Resources should immediately undertake to examine the feasibility of jurisdictional expansion for its CAFRA permitting program. In tandem with this recommendation, serious consideration should be given to reduction in the maximum impervious cover ratings allowed within the coastal growth rating system. Although it is not feasible to produce a delineation of exactly where the 80 percent/90 percent maximum impervious**

TABLE 21.

BASIC DESIGN CRITERIA AND BEST MANAGEMENT PRACTICES

(Cahill and Associates, 1988)

	OPPORTUNITY	MOBILITY	BIODEGRADABILITY	INTERVENTION
NON-STRUCTURAL				
Location Policies				
Stream Buffer Zone	+			
Estuary Buffer Zone	+			
Barrier Island Criteria	+			
NPS Exclusion	+			
Growth Policies				
State/County Zoning	+			
Infrastructure Design	+	+		
Site Design Policies				
Impervious Surface %	+	+		
Zero Maintenance	+	+	+	+
Regional Mitigation			+	+
STRUCTURAL				
Physical Removal of NPS				+
Dual Detention Basins				+
Oil/Grease Separators, Inlets				+
Wet Basins			+	+
Artificial Wetlands			+	+
Grassed Swales, Filter Strips		+		
Hydrologic Modification				
Recharge systems		+		
Porous Paving		+		+
Recg. Trenches/ Infil. Sewers				
Chemical Treatment of NPS				
Stream Neutralization			+	
CSO Treatment / Mgmt.				+

cover limits currently would apply, it appears as though this extraordinarily high coverage effectively could extend to vast areas, translating into densities far beyond the limits of most local zoning ordinances in many cases. Furthermore, such high coverage allowances literally defy rational stormwater management, as it is defined in this Manual, precluding most of the BMP measures outlined here. Given concerns regarding natural infiltration and preservation of the existing landscape and vegetative cover, a different approach to density management where impervious cover is reduced much more than is currently the case is strongly advocated here.

This Manual's selection methodology for BMP's is based on several important distinctions, the first of which is the origin or source of the runoff, with consideration being given to the type of NPS pollutants contained in that runoff. Then, the receiving water body is considered in terms of the degree and extent of tidal control. Next, the site plan is reviewed in terms of use type and intensity. Finally, BMP selection may be constrained by the depth to the water table at the site and the capacity of the existing soil mantle to remove pollutants effectively in percolating groundwater. The major distinctions are summarized below:

- **Differentiation by hydrologic regime (i.e., whether or not the site drains to tidally dominated waters)**

- **Differentiation by point of origin of runoff at the site (i.e., runoff from paved areas, roof areas, or pervious/vegetated areas)**

- **Differentiation by groundwater sensitivity features (i.e., nature and extent of the soil mantle, depth to seasonally high water table, and use of the existing groundwater resource)**

- **Differentiation by use type and intensity (i.e., residential and nonresidential)**

Additional discussion of these factors and the manner in which they influence BMP selection is in order here.

Differentiation by Hydrologic Regime

In the Atlantic coastal drainage of New Jersey, there exists an important boundary line, separating the land area which drains to fresh surface waters, both streams and lakes, from that area which drains to waters which are brackish, or controlled by the influence of the tide. The fresh waters are subject to stage increases from upland runoff, while the level of brackish waters is controlled hydraulically by the level of tidal fluctuations. In the tidal system, there is no quantitative reason to retain stormwater runoff; there is, however, significant qualitative benefit to be gained by retention of runoff. It has been amply demonstrated (Whipple, 1985) that a period of 4 to 20 hours storage allows the settling out of a significant fraction of several NPS pollutants, including COD, total phosphorus, and suspended solids. For those sites which are totally tidally controlled, emphasis of the stormwater system design should be the reduction and removal of pollutants. In these situations, the traditional peak rate of flooding concerns (no increase in peak rate for the 2, 10, and 100-year storms, pre and post-development) become secondary in importance, if not irrelevant, and water quality becomes the essential variable in stormwater management. Alternatively, in upland drainage systems which are not controlled by the tide, all of the storage criteria applied for hydrologic attenuation of peak runoff are valid and should be followed in all stormwater management systems, as well as relevant quality controls. Although there will probably be a considerable number of development applications which are "either/or" in nature and can be easily differentiated as either tidally dominated or not tidally dominated, other situations may be somewhat marginal. For those sites with both tidal and riverine dynamics to be taken into account, BMP selection should be responsive to both the need for quality control as well as peak rate management. In many instances, these functions can be met by BMP's which serve both needs. For example, plans may be submitted for sites which, although not directly discharging into tidal waters, are relatively close to a tidal connection. If this connection, an open channel, for example, is not encumbered in any way, if there are no critical junctures such as bridge crossings or other potential impediments, then tidal dominance may be assumed. As stated in earlier sections, the precise determination of tidal influence must be evaluated on each receiving stream on a case-by-case basis.

> **Hydrologic regime--defined here in terms of determining whether or not site drainage is tidally dominated--is a basic criterion in BMP selection in Atlantic coastal drainage and beyond. A permit application should be assumed to be nontidal unless the applicant presents adequate documentation demonstrating tidal dominance. If the site does not drain directly to tidal water, then the applicant must be able to demonstrate the absence of any impediments in the drainage connection between the point of site discharge and the tidal water as well as the absence of any adverse flooding effects (i.e., existing structures or land uses which might be adversely affected downstream), if quantitative peak rate concerns are to be set aside. This guideline in no way is intended to circumvent other relevant stormwater management regulations.**

This determination is important because imposing money and space-consuming BMP's to manage peak rate reduction when such quantitative effects are irrelevant must be avoided. In some tidally-dominated cases, being forced to engineer for peak rate reduction unnecessarily could mean the rejection of far more cost effective techniques for water quality control. It is critical to make this determination at the outset of stormwater management planning so that the truly meaningful variables can be dealt with in the most effective way. Although this tidal dominance determination seems straightforward, many regulators on the State, county, and certainly local levels do not necessarily share this perspective. Coastal Resources staff should communicate this position whenever possible to these other agencies, although at least in the short run, much unnecessary peak rate-oriented regulation will continue to occur at tidally dominated sites. In situations where increase in peak rate and related flooding concerns are real, of course, stormwater management must accomplish both quantitative and qualitative objectives.

Differentiation by Point of Origin of the Runoff

This BMP selection system distinguishes by point of origin of the stormwater--whether the runoff is from rooftops, paved areas, or pervious areas, because of the rather markedly different nature of the nonpoint source pollutants which can be expected to be generated from these different points of origin. For example, distinct strategies (BMP's) must be used for the hydrocarbons, heavy metals, and other suspended solids/particulates which are associated with paved areas. These pollutant loadings are usually related to vehicles and traffic. Because of the particulate form of the pollutants involved here, BMP's which in some way detain (or infiltrate) stormwater runoff and allow for adequate settling (or filtration) to occur are appropriate here. Runoff from pervious or vegetated areas alternatively can be expected to be the primary source of dissolved nutrients as well as herbicides and pesticides. Strategies of first choice for dealing with these types of pollutants are quite different from those which deal with particulate pollutants. In this case, we have opted for preventive strategies which take the form of natural vegetation landscaping as the approach of first choice. Second best techniques include wet ponds and marshes where the dissolved nutrients which negatively affect coastal waters can be taken up, consumed, and literally removed from the aquatic system. Finally, we single out rooftop runoff in most contexts as relatively nondegraded water which is dealt with more matter of factly (in areas where gull or other water bird populations are known to be great, where roosting on roofs would be significant, and where bird dropping deposits would therefore be great, some management technique must be provided, if this rooftop drainage is to be discharged into coastal waters without special treatment). Industrial rooftop drainage would have to be evaluated for special treatment.

In reality pollutants are not perfectly separated out by point of origin as this system would suggest. Paved area runoff can be enriched with nutrients and organic matter, for example. Nevertheless, the bulk of the pollutant loadings do in fact separate out in this fashion, such that there are compelling reasons to require certain BMP's for one type of runoff and not the other. To require dual-purpose detention basins or some other form of settling technique for dissolved nutrients such as nitrogen (lawn fertilizers) is wasteful and ineffective. Similarly, to require wet ponds or artificial marshes to remove particulate loadings would be inefficient, unless solids removal is incorporated, which might be disruptive. Therefore we have used this point of origin distinction as a mechanism to sort out BMP selection early in the process.

Such a system assumes that physical differentiation of runoff on development sites is practical, if not typical. Often times these runoff components intermix, as with roof leaders discharging to paved surfaces, but such situations usually occur only when the systems are not designed correctly. At present, most developments separate out these runoff types as the result of basic efficiency concerns, local development requirements, and/or good design practices. In summary, then, it should be reasonable to use this point of origin distinction as a basis for the BMP selection program--a program which reflects a strong concern for and emphasis on the problem of overenrichment of coastal waters, substantially linked to nonpoint source housekeeping and maintenance practices occurring on altered site landscapes during the post-development phase. This step in the decision matrix is based on this criterion:

> **Runoff should be differentiated by the applicant by point of origin: rooftop versus paved areas versus pervious areas. Rooftop runoff, in non-roosting and non-industrial areas, can be discharged directly into the ground or adjacent waterbody, due to its lack of pollutants. The applicant may elect to include this runoff with either paved or pervious area runoff, if appropriate measures are taken.**

Differentiation by Groundwater Sensitivity Constraints

Because an essential theme in this Manual's philosophy of stormwater management for the Atlantic coastal drainage is to maintain the natural infiltration of rainfall into the soil mantle, the capacity of the soil to filter NPS pollutants is a vital consideration in BMP selection. In many ways, this differentiation by soil properties is possibly the most important of all. It is through this screening that the method deals with the question of the adequacy of the soil mantle to properly renovate solubilized nonpoint source pollutants as well as to filter particulate pollutants. It is through this determination that we make sure that the existing groundwater resource is not contaminated. As a consequence, the BMP selection method hinges on a combination of variables which take into account on-site factors such as the depth to the seasonally high water table (SHWT) and nature and extent of the existing soil mantle. Additionally, this determination is intended to be sensitive more directly to the groundwater resource value itself by taking into account existing and planned use of the resource, including adjacent existing and proposed wells.

Contamination of New Jersey's groundwater resource has been a major problem throughout the State and is of the utmost importance within the Atlantic coastal drainage as well. As a matter of fact, because of the shallowness of the water table and sandiness of the soils, the vulnerability of the groundwater resource is that much greater as one moves toward the coast. This sensitivity is increased by the fact that coastal water supply, both municipal and private, tends to be groundwater based. The State understandably has taken considerable measures to make sure that further groundwater pollution does not occur. Thus, it is important that any stormwater management scheme be truly conservative and that the groundwater resource is adequately protected.

It is of paramount importance to fully exploit the natural renovating capacity of the soil to the extent possible when examining nonpoint source water pollution. Although the preference in nonpoint source management programs is to be preventive first, in those situations where preventive techniques cannot be applied, then the next best approach is to rely on natural functions which are in place. If the soil renovating potential is adequate and the potential for adverse environmental effects is minimal, then removal of nutrients from pervious runoff and removal of pollutants from paved runoff should exploit this natural function of the soil. Such approaches based on infiltration are considerably more effective and efficient than other alternatives such as creation of wet ponds and artificial marshes for pervious runoff or multi-chambered catchment basins and dual purpose detention basins for paved area runoff.

In operationalizing this determination, several important observations need to be made. First, although soils can be extremely complex in their composition and structure, the soils within the Atlantic coastal drainage appear to be relatively similar, with sand being the primary particle size. Clays and silts tend to be found infrequently. For example, the soils found in Ocean County, most of which falls within Atlantic coastal drainage, have considerable similarity (Table 22). The predominant feature of these soils is their sandiness and their rapid permeability (often 2 to 6 inches per hour or more). In fact, only a few soils (4) have horizons with permeability of less than 0.2 inches per hour, and these are not widely distributed. These soils are limiting for groundwater recharge because of the presence of clay layers, often creating a perched water table condition. They often have highly permeable sand layers both above and below these clay layers.

Detailed soils inventories and analyses for all soils within the Atlantic coastal drainage have not been prepared for this Manual. All judgments in this Manual regarding soils capabilities are, therefore, summary in nature. As a related research task of high priority, NJDEP should perform additional study on the soils characteristics within the Atlantic coastal drainage to be able to more accurately define renovating capabilities of these soils. In so doing, the scheme here hopefully can be refined and the assignment of BMP's will be more fine-tuned. This fine-tuning should maximize pollutant reduction capability for money expended on BMP's, without jeopardizing groundwater quality.

The prevalence of sand translates into relatively rapid to very rapid permeability, in contrast to so many soils found elsewhere and has special meaning for BMP recommendations which rely heavily on permeability. At the heart of the matter here is the capability of the soil to renovate waters flowing through it as the result of physical, chemical, and biological mechanisms. Soil microflora are extremely complex, with innumerable species of fungi, bacteria, actinomycetes, algae, and viruses

TABLE 22.

OCEAN COUNTY SOIL SERIES

SELECTED CHARACTERISTICS (SCS, 1977)

Series Name	Symbol	Texture	Hydro. Group	Perm. <0.2"/h	SHWT <12"	SHWT 18"-48"	CEC (meq/100 gm)
Adelphia	Ad	Sandy Loam	C			*	8-22
Alluvial land	Al		D		*		4-10
Atsion	At	Sand	D		*		1-7
Aura	Ar	Sandy Loam	B				3-8
Berryland	Be	Sand	D		*		1-7
Berryland, flooded	Bf	Sand	D		*		3-7
Collington	Co	Sandy Loam	B				10-22
Downer	Do	Loamy Sand	B				1-7
Dune	CB, DU						0-3
Elkton	Ek	Loam	D	*	*		10-20
Evesboro	Ev	Sand					2-6
Fallsington	Fa	Sandy Loam	D		*		5-10
Fill land, sandy	FL, FS						1-3
Fill land, tidal mar.	FM, PR						1-3
Hammonton	Ha, Hc	Loamy Sand	B			*	2-7
Keyport	Ke	Sandy Loam	D	*		*	5-10
Klej	Kl	Loamy Sand	B			*	2-6
Kresson	Kr	Sandy Loam	C	*	*		15-20
Lakehurst	Lh	Sand	B			*	0-3
Lakehurst, clayey	Lm	Sand	B	*		*	2-10
Lakewood	Lw	Sand	A				0-4

Made Land	MD					
Muck	MU		D	*		>15
Pemberton	Pe	Sand	A		*	5-10
Pits	PT					
Pocomoke	Po	Sandy Loam	D	*		2-12
Pocomoke, var.	Au	Loamy Fine Sand	D	*		2-12
Sandy land	Sl	Sand	A			2-6
Sassafras	Sa	Sandy Loam	B			2-12
Shrewsbury	Sh	Fine Sandy Loam	D	*		4-15
Tidal Marsh	TM		D	*		
Tinton	Tn	Sand	A			4-10
Urban land	UR					
Woodmansie	Wo	Sand				1-5
Woodstown	Wp	Sandy Loam	B		*	2-10

present. These species process organic material as a food/energy source in a variety of ways (Gray and Williams, 1971). Even in a sandy soil, where the surface area of the soil particles is low (72 sq cm per gram), significant pollutant reduction/processing takes place. In the case of stormwater and nonpoint source pollutants, the basic question becomes not only the ability of the soil to reduce organic material and filter particulate form pollutants from the stormwater inflow, but also its ability to remove the soluble pollutants such as the nutrients from this inflow. The most important chemical processes governing the removal of pollutants from stormwater inflow include adsorption, ion exchange, and chemical precipitation. A key soil parameter which measures the ability of a soil to remove contaminants is the cation exchange capacity (CEC) of the soil. Cation exchange values typically range from 2 to 60 meq per 100 grams of soil, with most soils having a CEC of between 10 and 30. As shown in Table 22, many of the sandy soils in Ocean County have CEC's less than 10, although some soils do have higher values.

> **According to EPA's Process Design Manual for Land Treatment of Municipal Wastewater (USEPA, 1977), soils with a CEC value of 10 or greater do offer at least moderate adsorption potential, which should be utilized to the fullest extent in stormwater management. Therefore this value of 10 meq per 100 grams of soil is used as a threshold value in this Manual. As will be discussed in more detail below, however, this CEC variable must be used in conjunction with other parameters, in order to provide adequate environmental safeguards. NJDEP should undertake additional research evaluating Atlantic coastal drainage soils and their CEC values in order to refine this criterion.**

Denitrification, where nitrogen is transformed in the subsurface environment, is another important process which occurs within the soil mantle. Nitrates percolating into the groundwater are reduced to gaseous N_2O or N_2, which is then released back into the atmosphere, through the action of ubiquitous facultative heterotrophs. More specifically, in the absence of oxygen, nitrate acts as an acceptor of electrons generated during the microbial decomposition process of various energy sources in the soil mantle (Canter and Knox, 1986). If nitrates are not transformed and reach groundwater, they become very mobile due to their high solubility and anionic form. Interestingly, within the coastal context where sandiness predominates and where water can move so quickly through the relatively shallow soil mantle, issues surrounding "opportunity" tend to be just the reverse of the types of concerns which so often have plagued designers of BMP's in so many inland areas. In suburban Washington and throughout the State of Maryland, for example, soils constraints frequently involve a <u>lack</u> of permeability, where presence of clay and other material will make infiltration practices basically unworkable. In coastal areas distinguished by sandy soils, the permeability variable is stood on its head. Here <u>excessive</u> permeability becomes the constraint. Thus, the presence of a clay layer as indicated in the several soils flagged in Table 22 actually becomes a positive feature, rather than a problem, insofar as renovating potential and feasibility for infiltration practices are concerned.

Depth to seasonally high water table or groundwater is an important criterion in the method here. In reviewing soils conditions, high water table soils exist throughout Atlantic coastal drainage. In fact, as shown in Table 22 for Ocean County, virtually all of the soils classified within Hydrologic Group D (very great runoff/very slow rates of infiltration) are so classified due to excessively shallow depth to seasonally high water table (less than 12 inches). A large number of additional soils have depths to seasonally high water table between 18 inches and 4 feet. While there is some renovating potential present here (O'Hare et al, 1986), the potential is limited and care must be taken when proposing infiltration BMP's in such a context. In fact, the State is in the process of modifying its recommendations for use of infiltration-type BMP's in the Division of Water Resource's stormwater management program from a varying depth of 2 to 4 feet to a minimum of 4 feet. If this criterion were to be incorporated into this coastal management scheme, infiltration BMP's effectively would be eliminated from use in Atlantic coastal drainage.

Depth to seasonally high water table has become a major factor in this Manual's method. Soils with seasonal high water table less than 12 inches are uniformly dismissed as having appreciable renovating potential. Soils with a seasonal high water table of more than 4 feet should be fully exploited and therefore infiltration and other BMP's are proposed. Soils with a seasonal high water table in the marginal category--12 inches to 4 feet--offer some renovating potential, but should be used only when other parameters demonstrate that renovation will be adequate. Seasonal high water table, then, is to be used in combination with other determinations such as type of proposed action (nature and extent of nonpoint source pollutants to be generated), as discussed below, as well as the groundwater use context variable. As discussed above, soils conditions, as measured by CEC and including special features such as clay layers, must be taken into account. Again, as with CEC threshold values, NJDEP is encouraged to perform additional research on these depth to seasonal high water table values. In-place monitoring of pilot projects would be useful.

Another variable important in this determination is the extent to which the groundwater is being relied upon for water supply, measured by existence of either private or public system wells. Here the concerns include number of wells and the yields and depths of groundwater withdrawals. Analysis of the groundwater dynamics under existing and proposed development conditions would, of course, be ideal. Such demonstration is certainly not beyond the scope of the applicant and should be requested by the NJDEP Coastal Resources reviewer. In the absence of this information, the NJDEP permit reviewer would need some sort of more straightforward mechanism to conservatively address the value of the groundwater resource. The screening criteria should be as follows:

Recharge systems for stormwater management should not be used where there is the potential for groundwater contamination of sensitive aquifers. Groundwater sensitivity will be assumed, unless the applicant is able to demonstrate that there are no private wells within 200 feet of the proposed development and no municipal wells within 500 feet of the proposed development recharge area.

NJDEP should undertake more detailed evaluation of this groundwater resource sensitivity variable as soon as possible. Elsewhere in NJDEP, work has already been done which could be incorporated into this evaluation and could make the scheme here more refined. All data relating to groundwater withdrawal rates, projected rates, well depths, as well as known information relating to the nature and extent of the aquifers, groundwater movement, and the like should be incorporated. In so doing, it is possible that BMP schemes for cost-effective infiltration could be given broader application, thereby making nonpoint source management considerably more cost effective.

Differentiation by Pollutant Source (Land Use Type and Intensity)

The BMP selection system here is also geared to be sensitive to the issue of the proposed type and intensity of land use development and, therefore, the potential intensity of the type of nonpoint pollutants to be generated. In cases where special pollution potential exists (certain industrial uses, solid waste facilities), special study should be conducted by the applicant prior to installation of any type of infiltration device. The depth to water table criterion is also tightened when considering typical nonresidential development, where hydrocarbons and metals loadings would be expected to be greater. This differentiation to some extent is highly approximated and therefore somewhat forced. For example, as residential development densities increase to high density multi-family development, resulting traffic levels and related nonpoint pollutant loadings increase as well, although nutrient loadings may actually decrease. Nevertheless, in most cases we would expect residential loadings for most nonpoint source pollutants to be considerably less than those for typical commercial or industrial development.

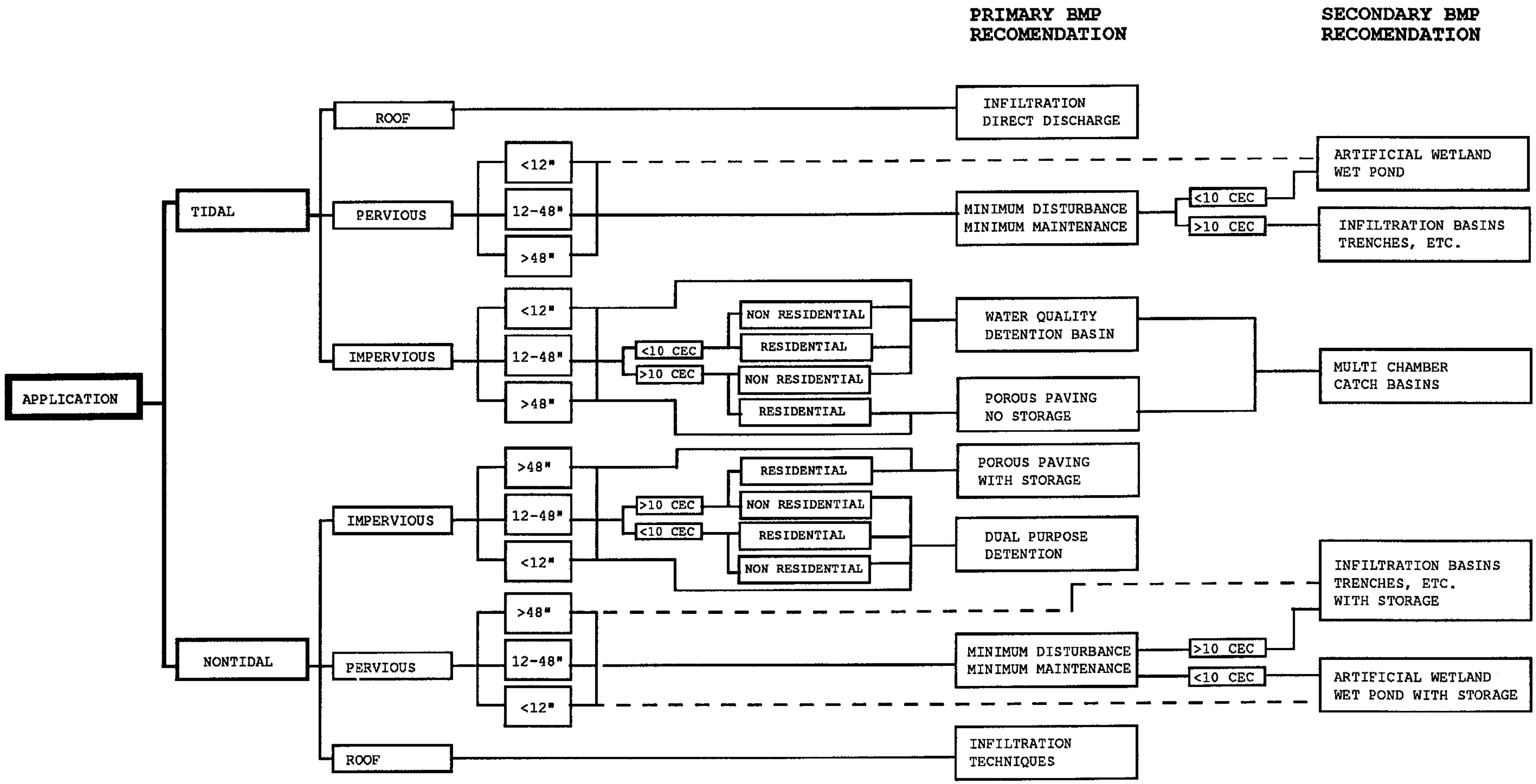
BMP selection should vary according to whether the proposed development is residential, nonresidential, or a use of special pollutional potential. At some point in the future, the Division may want to further refine this system and make BMP assignment in a more detailed manner by land use sub-category.

Operation of the BMP Selection Method: Summary

There is no doubt that the modest method or scheme here for BMP assignment is not perfect. Given its relative simplicity, much of the real world's complexity has been sacrificed, which ultimately will mean some amount of confusion and uncertainty during specific permit reviews. Some cases will be more complex and ambiguous than others. There is no easy solution to this predicament. Although no information is provided here on the the cost of our various BMP recommendations and the overall implementation of the method, much of what is advocated in this Manual here will require additional capital expenditures, although given the prevailing market in this area, incremental costs associated with additional stormwater BMP's should not be significant in most cases. Hopefully, some sort of expanded user fee system can be devised to equitably assign actual costs incurred to those responsible for the costs. The Division may also want to give consideration in the future to different program approaches, as the program evolves and is further refined. For example, one approach as discussed above would be to further refine many of the variables used as the basis for the BMP assignments here, so that the selection scheme and the criteria used by reviewers become considerably more focused and cost-effective. Alternatively, the Division might opt to reserve several specially trained permit reviewers for the permit applications deemed to be especially difficult or challenging. The Division could elect to conduct educational seminars for design and engineering professionals, emphasizing the importance of incorporation of these BMP's into future permit application submissions. In any case, there are a variety of directions in which the program could evolve from this point.

BMP Selection Model

The BMP selection process outlined in this Manual, with consideration of a number of site specific factors and selection of both primary (most efficient) and secondary (alternative with reduced pollutant removal efficiency) BMP's for a given proposal, lends itself to a certain thought process. A computer flow chart or decision matrix can be envisioned which allows the site designer to be guided through a number of decision points and be directed to the BMP which is best suited for pollutant reduction in a specific location within the Atlantic coastal drainage. Figure 26 is a diagram of such a BMP selection



CEC CATION EXCHANGE CAPACITY OF SOILS (MEQ PER 100 GMS. OF SOIL)
< 12" CATEGORY: DEPTH TO SEASONAL HIGH WATER TABLE
NOTE: IF ROOFTOP POLLUTANTS ARE SUSPECTED TO BE CONSIDERABLE (I.E., INDUSTRIAL OR OTHER USES, BIRD ROOSTING) THE RUNOFF MAY HAVE TO BE TREATED AS IMPERVIOUS RUNOFF.

Figure 26. Proposed BMP Selection Model (Cahill and Associates, 1988)

process. As experiences are gained and the process evolves, this matrix will evolve as well. If sufficient resource information were available in appropriate format (a potential application of the State's new Geographical Information System), this process could be performed by computer analysis on a broad scale for an entire municipality, county, or watershed. Such a pilot study would be an appropriate next step for the Division of Coastal Resources in order to evaluate the applicability of alternative BMP's within a diverse region.

The BMP selection process begins with hydrologic differentiations (tidal, nontidal, and degrees thereof) and then distinguishes by runoff source (pervious, impervious, and rooftop), both of which are reasonably straightforward. The method then differentiates by depth to seasonally high water table. In situations where water table is greater than 4 feet, infiltration practices are acceptable certainly for all types of rooftop runoff. For pervious runoff, our "minimum disturbance/minimum maintenance" landscaping BMP is the preferred recommendation; however, as an alternative, infiltration practices may be used for all development types, regardless of the groundwater use context. For paved area runoff, infiltration practices also are acceptable. In the other extreme, where depth to seasonally high groundwater table is less than 12 inches, infiltration is acceptable for rooftop runoff, but not for either pervious or paved area runoff, regardless of land use being proposed and regardless of the groundwater use context or soil type. Again, for pervious area runoff, the BMP preferred is the minimum disturbance/minimum maintenance approach, regardless of depth to seasonally high water table or soils or groundwater use context. For impervious runoff, the preferred technique is water quality or dual-purpose detention basins.

For situations where depth to seasonally high water table is between 12 inches and 4 feet (these depths are used here to be compatible with the county soil surveys), the determinations are more complicated. In this situation for pervious runoff, minimum disturbance/minimum maintenance is preferred, but infiltration is acceptable for residential projects where groundwater use context is not rated as sensitive. For paved area runoff, infiltration is acceptable for residential projects where groundwater use context is not rated as sensitive and where soils have at least moderate cation exchange capacity. In this situation, if special soil conditions such as clay layers can be shown to exist to promote renovation and filtering, then infiltration practices for pervious runoff from both residential and nonresidential projects would be preferable where groundwater use context is not sensitive.

BMP techniques themselves are described in greater detail in Chapter Five. As is the case with any method or scheme, variations on BMP selection are possible, if not probable. Hopefully, the scheme will stimulate creative solutions, responsive to the many different site contexts which exist. If the basic design criteria are followed in concept, the program should succeed in significantly reducing nonpoint source loadings to coastal waters.

CHAPTER 5.

BMP'S RECOMMENDED FOR NEW JERSEY'S ATLANTIC COASTAL DRAINAGE

CHAPTER 5.

BEST MANAGEMENT PRACTICES

Introduction

A variety of publications are available which do an excellent job in outlining various best management practices discussed in this chapter, such as *Urban Runoff: A Practical Manual For Planning and Designing Urban BMP's* by the Metropolitan Washington Council of Governments (Schueler, 1987) and the *BMP Handbook For The Occoquan Watershed* by the Northern Virginia Planning District Commission (NVPDC, 1987). Several older publications have dealt with the appropriate BMP's available for agricultural settings and are included in the list of references, but because there is only a very limited amount of land in active cultivation within the Atlantic coastal drainage (most of that is specialized agriculture, such as cranberry bogs and nurseries), agricultural BMP's are of only limited interest in this Manual. Several of these manuals are on file at the Division of Coastal Resources and can be consulted there.

All of the manuals dealing with BMP selection and application in other environments should be used carefully, as in most cases they have been designed for application in physiographic regions different from the New Jersey Atlantic coastal drainage. Generally, we recommend their use specifically to describe a particular BMP, but urge caution in their guidance regarding BMP selection criteria. For example, the Schueler report is an excellent resource and provides good guidance in terms of actual definition and design of BMP's. At the same time, we are in disagreement with much of his chapter on BMP selection criteria. Porous paving and underground recharge beds are deemed by Schueler to be infeasible in areas where slopes exceed 5%. To the contrary, this BMP approach can be incorporated in steeply sloping areas very effectively, with terraced parking bays stepping down a slope, assuming that other performance criteria are met. Admittedly, this particular steep slope criterion is of little relevance in the gently sloping New Jersey coast, but it serves to demonstrate potential difficulties with attempting to reach conclusions as to the suitability of possible BMP's without considering local site constraints and opportunities. These manuals can be used for a general understanding of BMP design; however, specific applications and installation specific to New Jersey coastal regions, as outlined in Chapter Four, far transcends information contained in these reports.

In the sections which follow, the BMP's which are recommended for use in New Jersey's Atlantic coastal drainage (and beyond) are discussed in some detail. Some of these measures have already been used, and both NJDEP staff and site designers are familiar with their design and application. In most cases, however, their use has not been particularly widespread and there will be learning involved in the design process, both from the State's and applicants' perspectives. Therefore, some discussion is provided for each of the techniques which follow. Typically, a definition of the BMP technique is followed by an example. Illustrations of these various BMP's are included, many of which are excerpted from the manuals referenced or based on actual designs engineered by the authors. Also included is a discussion of BMP effectiveness, including research results from field monitoring of BMP applications, where available. Finally, the problems and issues associated with specific BMP's and their implementation in Atlantic coastal drainage areas are considered.

Minimum Disturbance/Minimum Maintenance Site Development

"Minimum disturbance/minimum maintenance" is a term we assign to a highly conservative approach to site development, where clearing or site grading is allowed only within a carefully prescribed building envelope. This disturbance area would include the land required for the structure and any related utilities, drives, and walks. Following construction, disturbed areas immediately adjacent to the structure and drives/walks are revegetated with carefully selected indigenous species, requiring minimal or no maintenance. Thus the completed site will not require ongoing fertilization or applications of herbicides and pesticides, although minimal maintenance and cutting may be appropriate. Lawns and gardens are discouraged and/or not permitted, but special plantings may be accommodated with proper containerization.

First and foremost, minimum disturbance/minimum maintenance stands out among the recommended BMP techniques because it is both non-structural in design and preventive in nature. Most notably, the approach eliminates the need for ongoing fertilization of yard areas, which are both significant sources of coastal water pollution and costly to owners as well. The undisturbed site areas are left to grow naturally and do not require applications of nutrients. Furthermore, under normal circumstances, these undisturbed areas also will not need pesticide or herbicide applications, further minimizing chemical usage in the coastal drainage. Because this approach promotes continuation of natural recharge and infiltration without the threat of surface contaminants, the indirect sources of pollution, as produced by increased stream flow and surface runoff, are also eliminated. For all of these reasons, minimum disturbance/minimum maintenance becomes the BMP of first choice in the New Jersey coastal drainage.

Minimum disturbance/minimum maintenance as a technique focuses on those nonpoint source pollutants which have as their source pervious areas, generating NPS pollutants such as nutrients (nitrogen and phosphorus), COD, pesticides, and herbicides. By definition, this approach is not oriented toward impervious surfaces, with runoff containing NPS pollutants such as metals and petroleum hydrocarbons.

As we have defined it here, minimum disturbance/minimum maintenance (sometimes called "zero maintenance") can be applied generally to a total development proposal or to an individual lot. It is certainly true that as the parcel size diminishes, successful incorporation of this approach becomes progressively more difficult, although the same could be said of virtually all BMP techniques (to even greater degrees in many cases). Certainly, use of such an approach for extremely small parcels in already built-up areas becomes debatable, where small and isolated islands of natural vegetation would result. In such a context, the probable difficulty in gaining local acceptance of the minimum disturbance/minimum maintenance approach could be so great and so costly as to outweigh any positive functions served. At the same time, the approach can clearly be compatible with larger areawide planning approaches, extending well beyond the limits of particular parcels or sites. For example, the approach can and should overlay onto a natural drainage system protection plan, where actual disturbance or construction would not be allowed within drainageways and adjacent buffer zones in any case. In such a context, natural areas left intact as the result of minimum disturbance/minimum maintenance would reinforce the natural functions of the drainage system. In a sense, minimum disturbance/minimum maintenance is the logical extension and refinement of the natural drainage system concept.

Minimum disturbance/minimum maintenance is compatible with most land use categories and development proposals, although some uses become more problematic than others. Probably the most difficult land use to incorporate reasonably under this approach would be the traditional golf course, which requires considerable maintained area with associated chemical application.

Similarly, some uses such as parks with active recreational areas require maintained grass areas. These uses should not necessarily be excluded from coastal drainage areas, although such uses should be managed carefully so that chemical application is minimized. A research task which NJDEP should consider would be a more exhaustive list of these problem land uses, together with an evaluation of the options available for their management within the coastal drainage. Relatively speaking, we would not expect nonpoint source loadings from these particular uses to be significant and to constitute a major source of coastal water pollution. Minimum disturbance/minimum maintenance could be integrated into single- and multi-family residential developments very successfully, as well as office parks, retail facilities, institutional uses, and the majority of other uses. Because much of the "back yard" recreational amenity would be sacrificed in those areas where this technique is applied, careful consideration should be given to adequate provision of formal and informal recreational areas.

Perhaps most importantly, the concept of minimum disturbance/maintenance site development is one that lends itself to application on existing parcels. It is certainly an easy BMP to "retrofit", since it represents the removal of existing, high maintenance vegetative material. Once the concept finds general public acceptance, the reduction of NPS nutrient and chemical loadings to coastal waters may be best accomplished by doing nothing, in a physical sense, to landscaped areas.

Can such a dramatically different approach to development be made acceptable to the public? Two notable developments which are presented here as case studies demonstrate that, however radical such an approach may appear, this concept can be embraced by the public at large, for both seasonal and year-round use, if packaged in an aesthetic and creative fashion. One needs only to consider the model designs and envision such structures placed on the New Jersey barrier islands, in lieu of the current hodge-podge of tract housing units.

Two notable developments which are representative of coastal development executed with a high degree of environmental sensitivity, particularly with respect to minimum disturbance and reduced maintenance concepts, are Bald Head Island, North Carolina and The Woodlands, Houston, Texas. While developed at different times and under different market conditions, they both serve as examples of attractive, desirable mixed use developments which have managed to fit within the site constraints of their particular environment. They prove that this concept can be embraced by the public at large, including both seasonal and year-round residents. Appendix B offers more discussion and examples of specific site planning and design features for these two minimum disturbance/minimum maintenance cases studies.

Basic overall guidance on implementation of a minimum disturbance/minimum maintenance approach is provided in this Manual. The two examples discussed, the Woodlands and Bald Head Island developments, provide evidence that the approach, as radical as it seems at first, can indeed be implemented and successfully marketed. As a matter of fact, this approach should offer great promise from a user perspective. Given the fact that so much of the existing and projected development in the Atlantic coastal drainage is seasonal or tourism related, elimination of costly and time-consuming maintenance requirements such as lawn mowing, that sometimes must be performed in the absence of the owner, should be a boon to the overall shore market. Presumably, recreationally oriented users want to be freed of as many ownership maintenance responsibilities as possible, including ongoing lawn fertilization and spraying. Secondly, to the extent that development is retiree-oriented, elimination of many of these responsibilities should be quite compatible with retirement living. Thirdly, the natural landscape can seem unaesthetic to some, appearing overgrown and poorly managed. Nevertheless, this vision is flawed--the beauty of the natural landscape will come to be appreciated over time. Opposition to minimum disturbance/minimum maintenance initially will probably be considerable, simply because the approach appears to be so different. As the case studies demonstrate, however, the idea can be accepted even in areas with known traditional values.

Additional research needs to be conducted in the area of minimum disturbance/minimum maintenance, including the following questions:

- o what exactly should be the limits of disturbance as applied to different types of land uses, at different densities?
- o what native vegetation species are appropriate for replanting in disturbed areas?
- o to what extent is this approach compatible with municipal and county regulations? is it compatible with the SCS programs for E & S control?
- o if incompatibility exists with these other programs and regulations, what is the best way to resolve these contradictions?
- o should the system be made more sensitive to other variables, such as location? (i.e., barrier island versus mainland)

These and other questions need to be addressed in greater detail by NJDEP in the future.

Porous Paving

Porous paving is a bituminous paving material which has all of the structural properties of asphalt cement, but uses an aggregate mix which excludes the fine particles. The base stone used below the pavement is comprised of a uniformly-graded aggregate, usually in the 2 to 2.5 inch size range, which provides storage capacity for infiltrating rainfall within the void space of the aggregate. This stored rain gradually percolates into the soil mantle below the bed, based on the permeability of the soil. A layer of synthetic filter fabric is used between the gravel bed and the soil to prevent the migration of fines into the void spaces, while allowing infiltration. The original concept of this design (Figure 27) was developed in the 1970's at the Franklin Institute in Philadelphia (Fielding and Howe, 1975), and has been modified in design (Figure 28) through a number of field applications (Cahill and Adams, 1988).

The critical function of porous paving is to reduce direct runoff and to recharge the groundwater aquifers; as a matter of fact, post-development runoff can actually be <u>reduced</u> below pre-development runoff from natural vegetation (Figure 29). Essential here is the ability of the underlying soils to percolate adequately. If soils textures are very clayey, water table is high, or depth to bedrock is minimal, porous paving is generally not used, although in situations where site constraints prevent any surface storage of excess runoff, it may still prove economical to store runoff in sub-surface beds with subsequent release.

The hydraulic design is greatly influenced by the infiltration capacity of the soil, but the ability of the soil to remove NPS pollutants is dependent on sorption, where both solubilized and particulate form nonpoint pollutants become bound to soil particles through cation exchange (see Chapter Three). Actual data on the efficiency of pollutant removal beneath porous paving systems is quite limited, but much is known concerning the efficiency of pollutant removal in soils. As discussed in Schueler:

> "...Most of the sorption occurs within the first foot of soil, and is bound up for long periods of time (US EPA, 1977). The greatest sorption of nutrients and metals occurs in

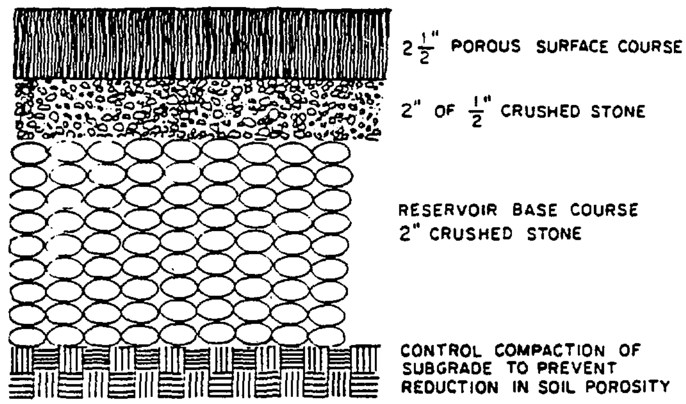
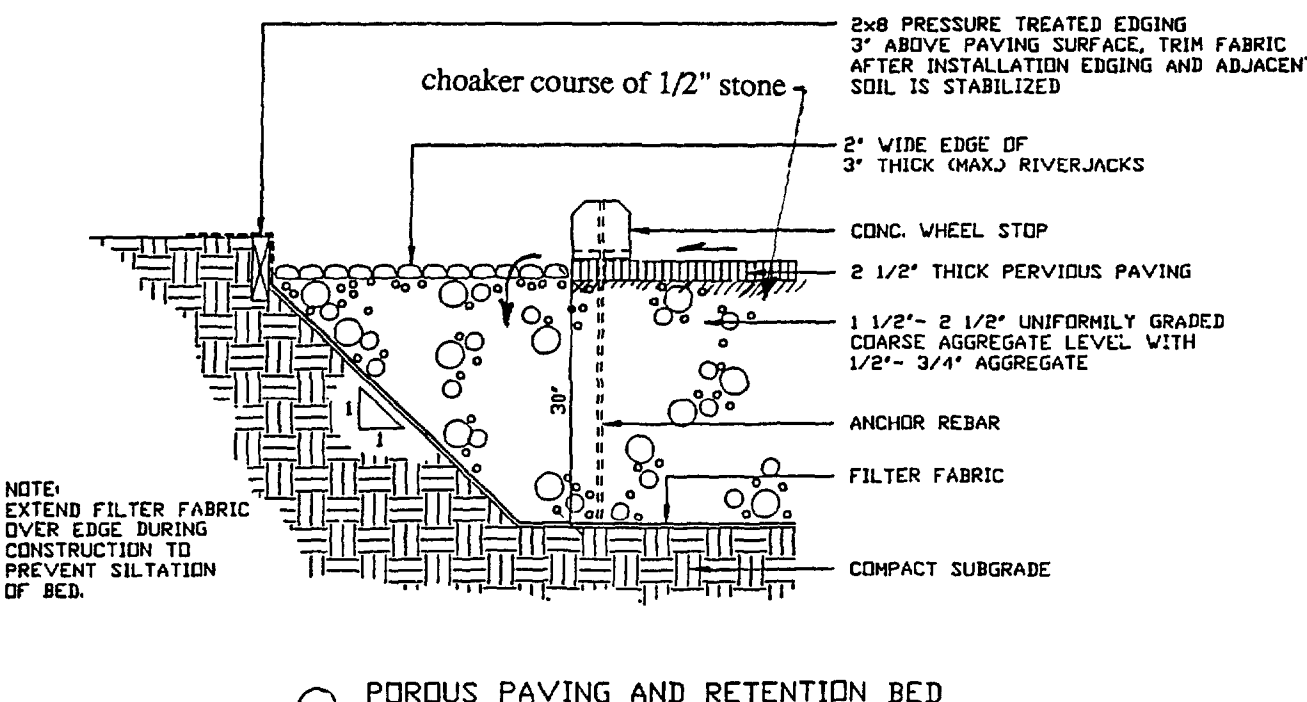
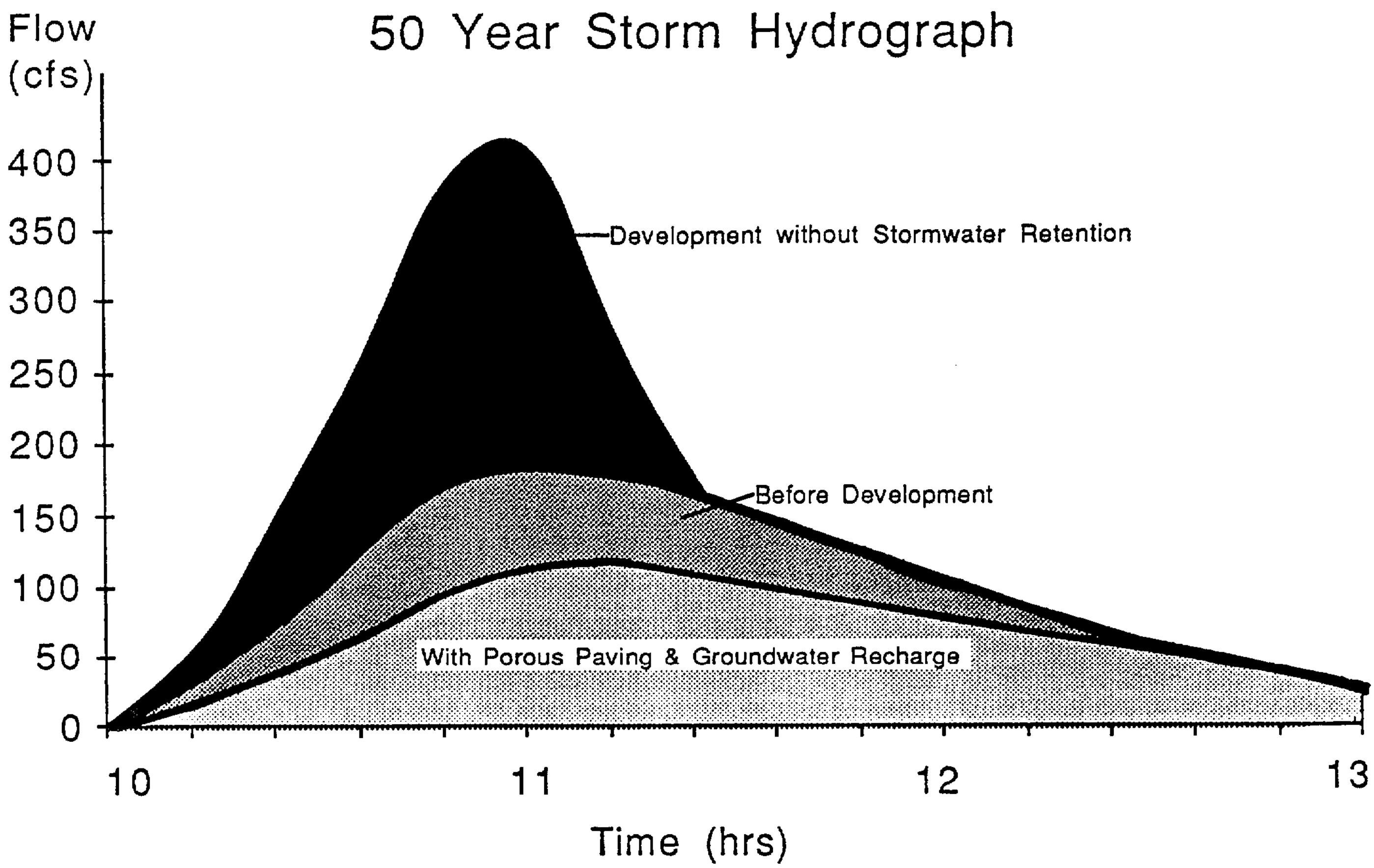


Figure 27. Original Design of Porous Pavement (Thelen and Howe, 1978)

Figure 28. Current Design Standard for Porous Pavement (Cahill and Associates, 1988)



EDGE INFILTRATION SYSTEM TO ASSURE FLOW INTO BED IF PAVING CLOGS



Reduction In Runoff Peak Flow

The use of porous paving also has a direct benefit in reducing the peak of runoff which normally results from a paved surface. By allowing rainfall to effectively pass through the pavement and be retained in a stone bed beneath, the impact of runoff is actually less than it was before development. The hydrograph shown here was developed in the model analysis of a site in Wilmington, Delaware, for the DuPont Corporation.

Figure 29. Modification of Hydrograph by Porous Paving (Cahill and Associates, 1985)

soils with a high content of clay and/or organic matter. Conversely, sandy soils exhibit much lower sorption rates. The same trend holds true for bacterial densities (US EPA, 1977). Unfortunately, soils that maximize sorption and bacterial growth also have low and sometimes unacceptable infiltration rates."

Aerobic bacteria within the soil also consume and reduce organic matter in the runoff, provided that the soil gets a chance to dry out every few days.

Typically, porous paving consists of several layers, including:

o the porous pavement itself (usually 2.5 to 3 inches in thickness, depending upon bearing strength requirements and traffic activity), applied in a single lift.

o a thin layer of smaller crushed stone (also called the "choker course"), usually about 0.5 inch in diameter or less, which provides a stabilized surface for placement of paving over the base stone. This layer cannot be excessively thick or it will not provide a sufficiently stable surface for placement of bituminous paving.

o a third layer, the reservoir base course, consisting of crushed stone of larger diameter, usually 2 to 2.5 inches in diameter. This layer is of variable thickness, depending upon the design criteria and respective storage needed for any particular situation. For example, in tidal areas where the attenuation of storm peaks is irrelevant, storage need only be adequate to contain the 1-year or water quality design storm and, therefore, would be relatively shallow. In other nontidal contexts, the thickness of the reservoir base could be much greater. Some designs are 30 inches or more in bed thickness.

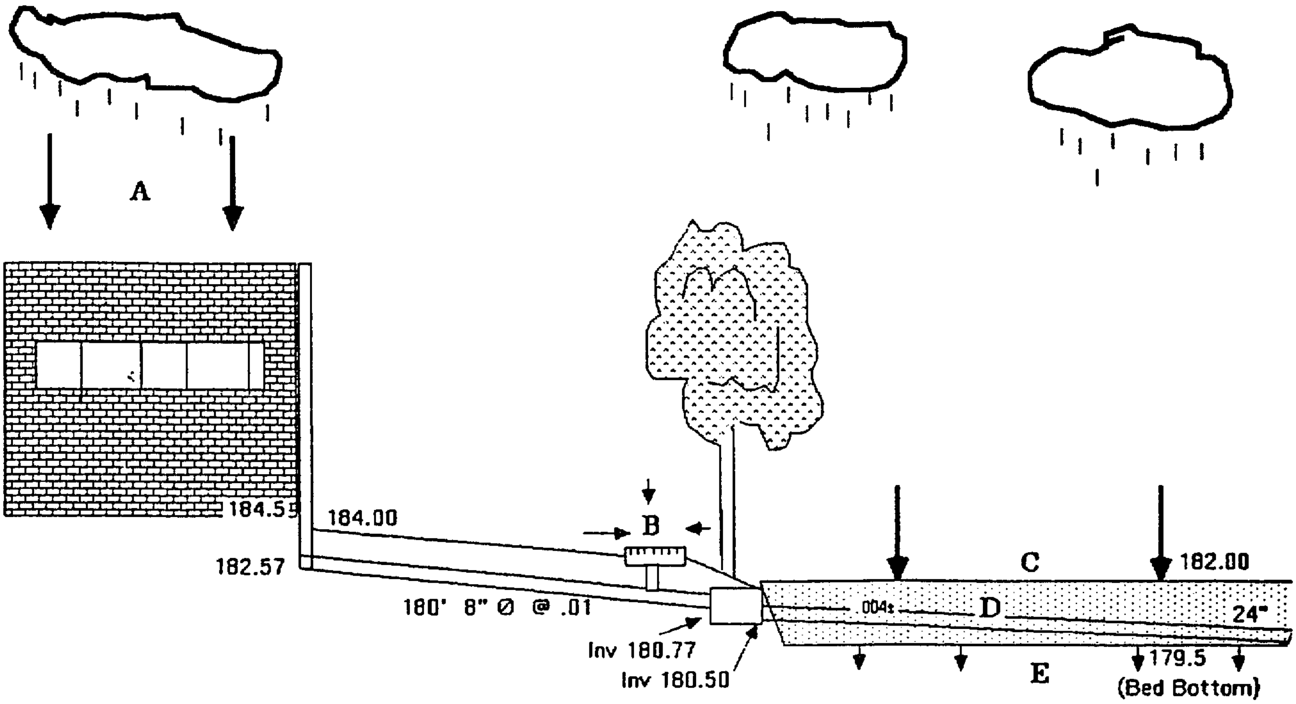
o at the bottom of the stone bed is a layer of filter fabric, separating the reservoir base from the minimally compacted/minimally disturbed subgrade. The fabric should be extended beyond the edge and folded over during seeding and vegetation of berms to protect the bed. When stable, the edge is trimmed.

Porous paving should be used for runoff from paved areas and should not receive sediment-laden runoff from the pervious or vegetated areas of the site during or after construction. Porous paving and groundwater recharge systems can be and have been designed to receive runoff from roofs, with conveyance directly to the bed (Figure 30). This separation of runoff type is critical in order to prevent the filling up of void spaces, as well as the accumulation of particulates in the choker course and then further down at the bottom of the reservoir base course at the interface with the filter fabric. In all of these situations, accumulation of particulate matter will lead to clogging and therefore must be avoided. Informed contractors and thorough specifications are important.

The ability of a porous paving design to reduce NPS pollutants as well as offer hydrologic and geohydrologic benefits is documented by Schueler (1987):

"Porous pavement has a high capability to remove both soluble and fine particulate pollutants in urban runoff, and also provides groundwater recharge, low flow augmentation, and streambank erosion control. Its use is generally restricted to low volume parking areas, although it can accept runoff from rooftop storage or adjacent conventionally paved areas...."

"When properly designed and carefully installed, porous paving has load bearing strength, longevity, and maintenance requirements similar to conventional pavement. Some other advantages of porous pavement are reduced land consumption, reduction or elimination of the need for curb and gutters and downstream conveyance systems, the preservation of the natural water balance at the site, and a safer driving surface which offers better skid resistance and reduced hydroplaning."



A. Precipitation is carried from roof by roof drains to storage beds.
B. Stormwater runoff from impervious areas and lawn areas is carried to storage beds.
C. Precipitation that falls on pervious paving enters storage beds directly.
D. Stone beds with 40% void space store water.
Continuously perforated pipes distribute stormwater from impervious surfaces evenly throughout the beds.
E. Stormwater exfiltrates from storage beds and into soil, recharging groundwater.

Figure 30. Conceptual Design of a Porous Paving - Groundwater Recharge System (Cahill and Associates, 1986)

Some jurisdictions (State of Maryland, for example) require that soils have a minimum infiltration rate of about 0.25 inches per hour for installation of porous paving, restricting their application to soils of Hydrologic Soil Group A or B. In the New Jersey coastal drainage context, however, the primary constraint is not so much the lack of infiltration capability, but excessive infiltration in many soils. Infiltration may be so rapid in sandy areas that the soil's natural renovating capabilities cannot be achieved, allowing nonpoint pollutant loadings to infiltrate directly into the groundwater. As a consequence, we have refined the system here to take into account this particular constraint, by introducing the variable of cation exchange capacity of each particular soil type (see earlier sections). Where a minimum threshold of cation exchange capacity or CEC is determined (CEC greater than 10 for a soil with at least 12 inches to the seasonally high water table), then porous paving is deemed to be feasible. Additionally, aerobic decomposition and chemical precipitation also occur within the soil mantle as runoff infiltrates through the soil.

Porous paving stands out as the BMP of choice for paved area runoff because it is the most effective way of naturally removing pollutants, assuming that the necessary soil and other standards are met. Other BMP's relying on sorption/cation exchange in the soil mantle, such as infiltration basins or trenches, can be incorporated into this basic design approach, depending upon volumetric needs, but usually represent increased construction complexity and costs. Porous paving is the ideal BMP and preferable from a hydrologic perspective because it maintains, if not improves, site hydrology and eliminates the need for BMP's elsewhere on the site. It also preserves valuable open space which may be better suited for environmental habitat and passive recreation, in lieu of stormwater management structures. Figures 31 and 32 offer two examples of site designs incorporating porous paving and groundwater recharge systems. While they are both situated over consolidated aquifers in upland environments, the design concepts are valid and applicable in the Atlantic coastal drainage.

Effectiveness and Efficiency

Several studies have been conducted on the ability of porous pavement systems to remove NPS pollutants. Many of these studies have been undertaken in suburban Washington (Maryland and Virginia; Schueler, 1987):

> "Two long-term monitoring studies have been conducted in the Washington area on partial exfiltration systems by the OWML (1986b, 1983) in suburban Maryland and Virginia. In both cases, the pollutant export over a series of storms was monitored at a terminal underdrain, and compared to pollutant loads in the runoff from adjacent conventional pavement. Both partial exfiltration systems exhibited similar and quite high removal capabilities. Mass removal of solids was 85% at the Prince William County, Virginia site and 95% at the site in Rockville, Maryland. Approximately 65% of the total phosphorus and 75-85% of the total nitrogen load was removed at both sites. Removal of trace metals, such as zinc and lead, at the Rockville site approached 98%, and over 80% of the COD load was effectively removed."

The BMP Handbook for the Occoquan Watershed reports that EPA's Nationwide Urban Runoff Program (NURP) results indicated remarkably high pollutant removal efficiency for most pollutants in the porous paving installations which were studied. Approximately 60 percent of the total phosphorus was removed and 88 percent of the total nitrogen was removed, according to EPA 's 1983 results. According to Weland and Grizzard's *Interim Progress Report - Davis Ford Park Urban BMP Demonstration Project*, a project undertaken by the Occoquan Watershed Monitoring Laboratory, phosphorus removal for that installation reached 62 percent. At the present time, the USGS in conjunction with the State of Maryland's Water Resources Administration, Division of Sediment and Stormwater is involved in a 5-year study on the water

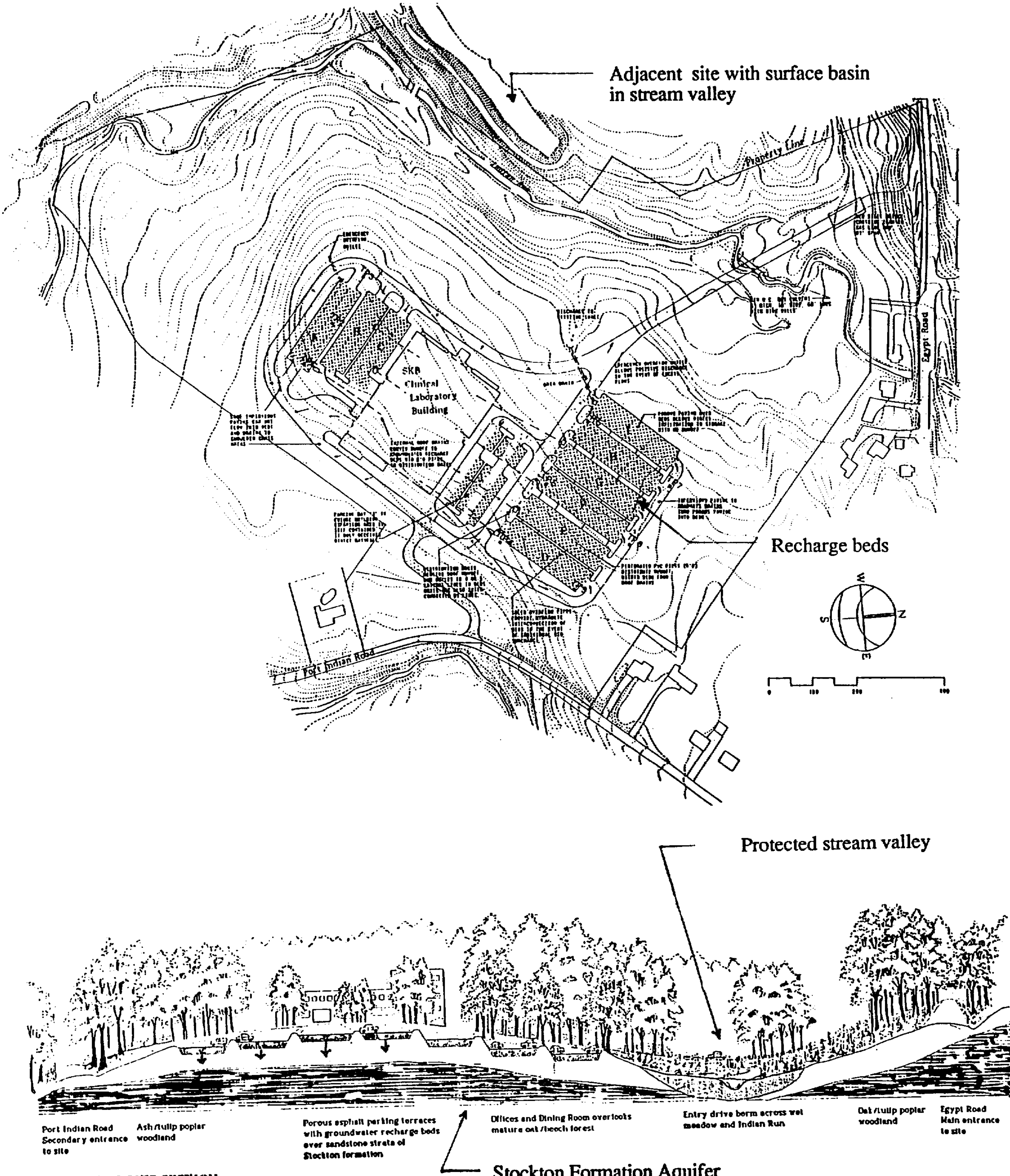
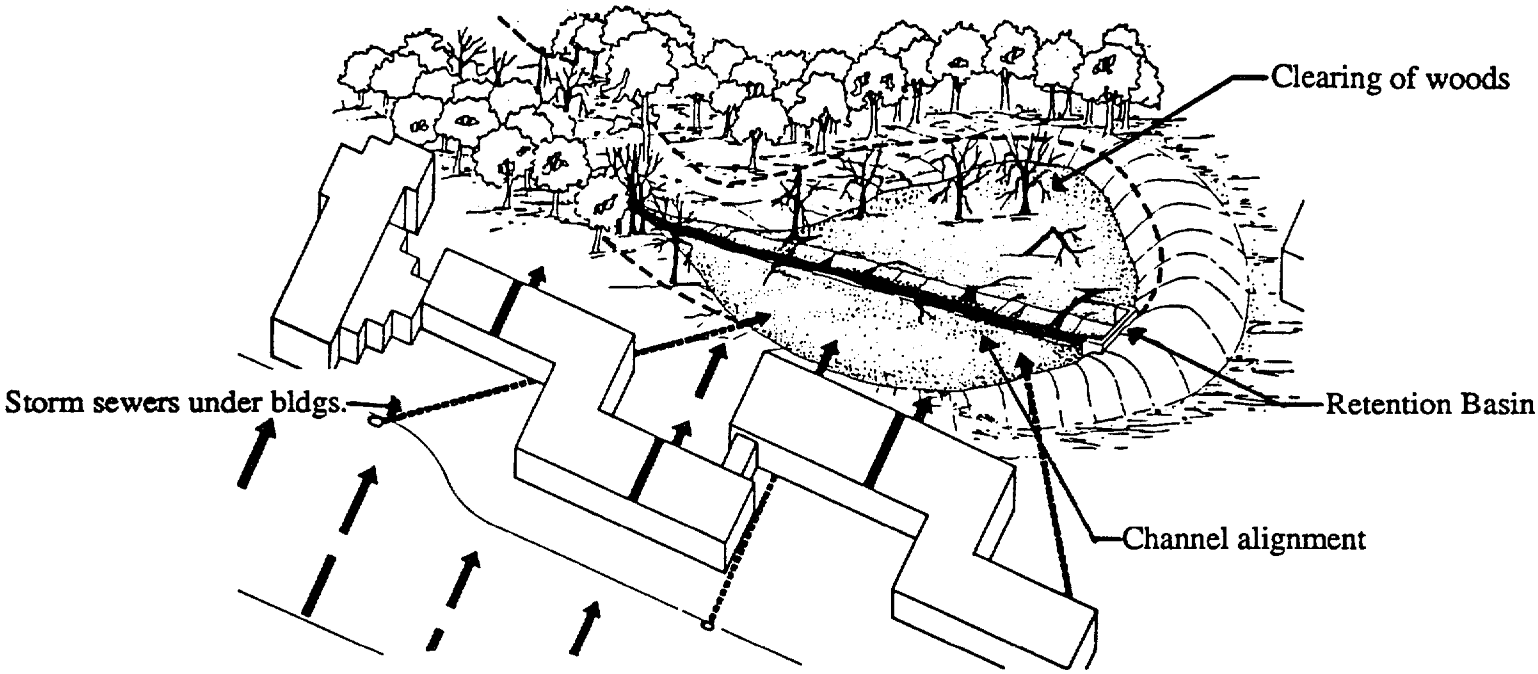
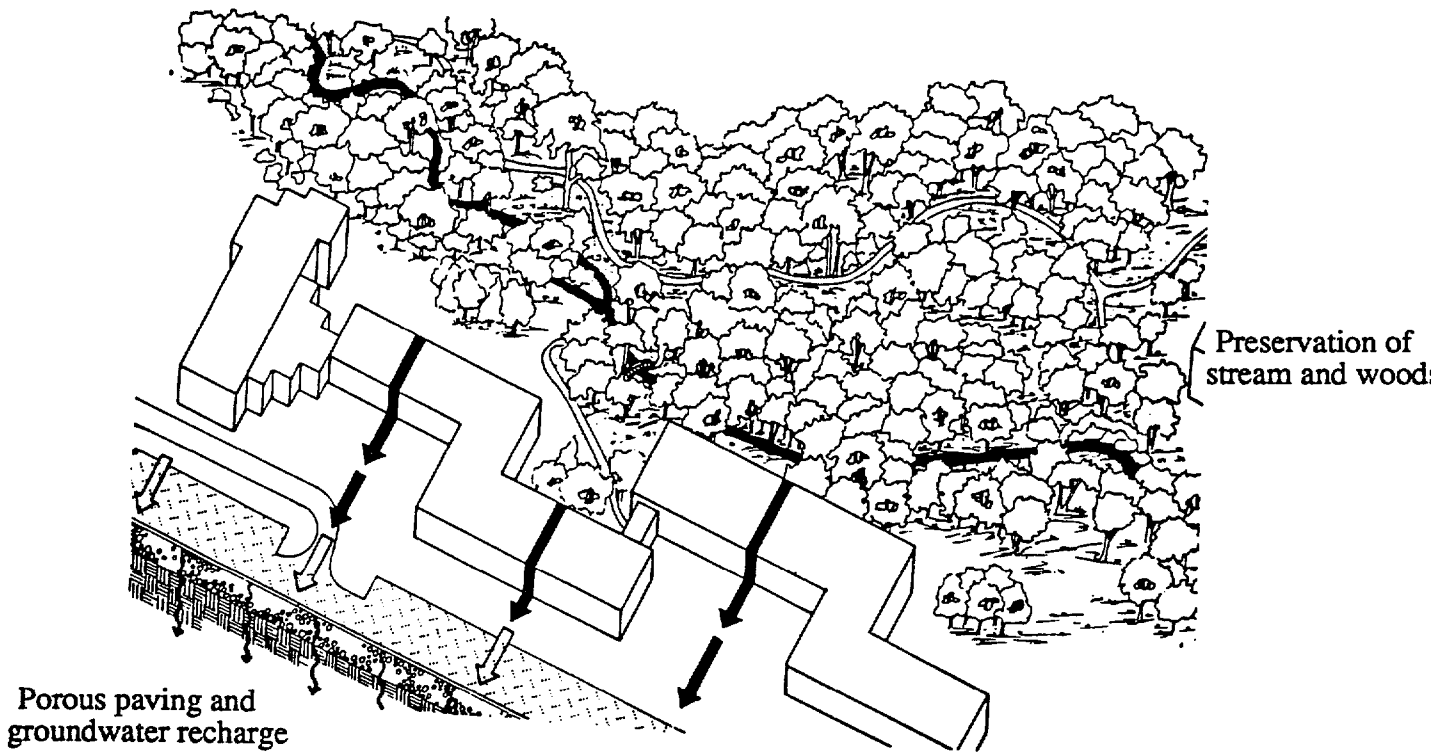


Figure 31. SmithKline Beckman Laboratory - Groundwater Recharge System (Cahill and Associates, 1986)



ORIGINAL STORMWATER SYSTEM DESIGN



POROUS PAVING - GROUNDWATER RECHARGE SYSTEM

Figure 32. Du Pont Research Center - Groundwater Recharge System (Cahill and Associates, 1985)

quality effects of porous pavement, evaluating several coastal and Piedmont sites. Results are to be available within the coming year.

Pollutants of concern here include oils and greases (hydrocarbons) and heavy metals, typically associated with vehicles. There will be some amount of bacteria from human (and non-human) activity in this runoff as well as elevated levels of COD and some lesser quantities of nutrients. Assuming that the soil mantle is adequate, porous paving with natural infiltration can be remarkably effective in terms of removal of these nonpoint source pollutants.

Specific Directions

It is recommended that porous paving be the preferred BMP for paved area runoff in both tidal and nontidal regimes, as long as the soil mantle is of adequate thickness and quality. More specifically, if the depth to seasonal high water table is greater than 48 inches, porous paving should be the preferred BMP in most situations. Where the planned site use includes both a high intensity use, such as a commercial or industrial and where the existing soil has a cation exchange value of less than 10 and where there is known groundwater reliance, then use of porous paving may not be acceptable and should be replaced by either water quality detention or dual purpose detention basins. Extent of the recharge bed is determined by the tidal-nontidal differentiation. For a mantle of lesser soil thickness (SHWT between 12 and 48 inches), porous paving is preferred in only those conditions where the soil cation exchange values are reasonably good (in excess of 10) and where the intensity of the proposed use is not great (i.e., residential uses). In these situations, a reasonably thick mantle with a good CEC is adequate to remove the lesser pollutant loadings associated with residential uses. In all other situations, porous paving is viewed to be a potential source of groundwater pollution and therefore should be replaced by either water quality/dual purpose detention basins, or possibly artificial wetlands.

Porous paving design variations include systems which are designed to provide only partial exfiltration of stormwater into the groundwater and that may have drainage provided from the recharge beds to a traditional storm sewer system. However, any such systems which detract from the critical natural renovating functions provided by the soil similarly detract from pollutant removal capability and therefore are not recommended.

Porous paving usually is not used for areas experiencing especially large volumes of traffic or heavy vehicle traffic, although a variety of techniques can be used to increase the load-bearing capacity of a porous paving installation as well as its durability. Often, these limitations can be overcome by using a combination of both porous and impervious paving, with an impervious ring road or higher activity area draining onto a porous paved lower activity zone. Recharge beds should drain in no more than 48 hours, where storage is a primary bed function. Porous paving should probably not be placed immediately adjacent to foundations and basements in order to prevent infiltrating waters from seeping into sub-grade structures.

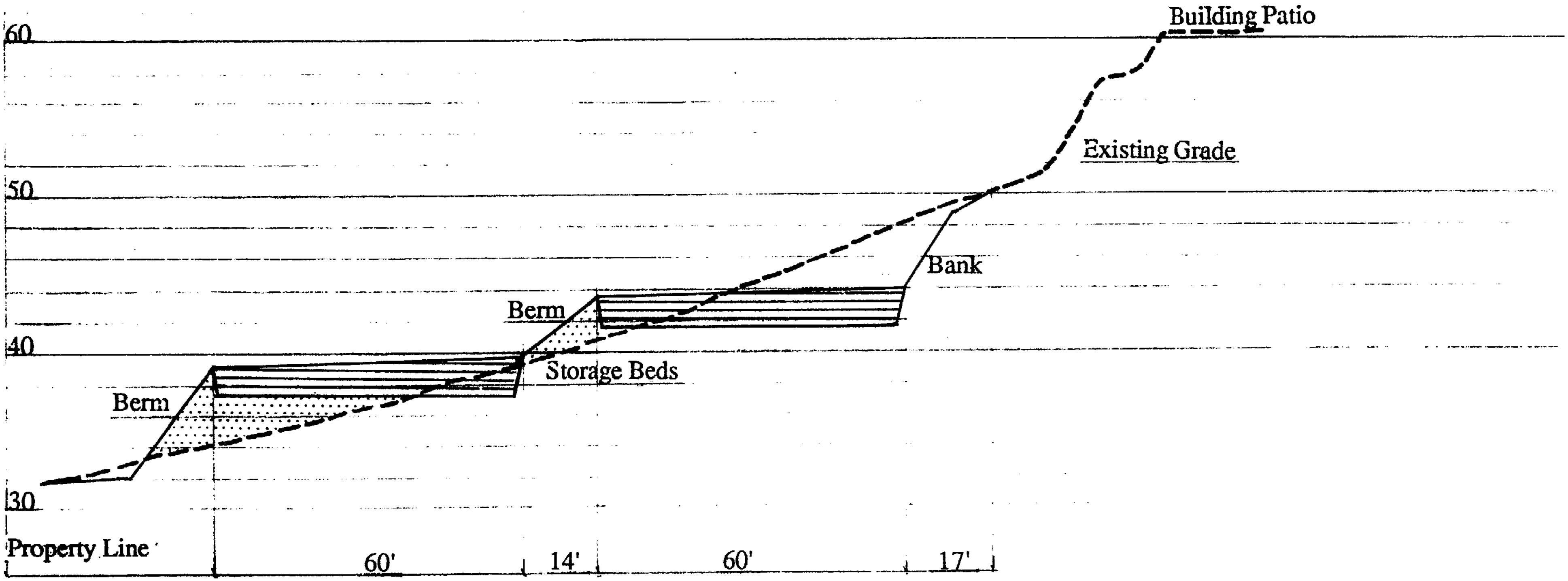
Porous paving installations can be vacuum swept periodically (once or twice per year) to maintain pore openings. Frequency of sweeping will be a function of the proposed use and intensity of activity occurring as well as the nature of the site context. For example, in coastal areas where adjacent sites are relatively bare and air-borne particulate matter is expected to be considerable (mall parking lots in areas of considerable disturbance or development activity), frequency of sweeping will have to be increased. In low usage areas with heavy vegetation growth onsite and offsite (e.g., low density residential developments in wooded areas), frequency can be reduced and possibly even eliminated. As an added measure of insurance against pore clogging, an edge design can be incorporated (Figure 28) which allows runoff to flow into the bed even if the porous surface becomes sealed.

Monitoring wells should be included in each porous paving installation. In situations where infiltration is slow (rare in the coastal drainage), an observation well located at the downslope end of the recharge bed should be installed during construction so as to enable checking on infiltration rates and problems which could develop regarding clogging of the beds. Alternatively, the Division should require development of a monitoring well at each installation which would extend to a depth below the recharge beds at a representative lowpoint (downgradient location) in the porous paved area. The well should be sunk as deep as possible, though at the same time must be above the seasonally high water table. In most cases, this would translate into relatively shallow wells that are not expensive to install. Sampling would be done after each significant rain event (1-year or greater storm) for the first year, involving all relevant parameters (Table 19). The precise nature and extent of this sampling program would be left to the discretion of the Division in each permit application case. Over time, this type of sampling would provide far more meaningful data relating to the water quality effectiveness of the porous paving installation and the extent to which design criteria would have to be tightened or liberalized. If sampling results demonstrated that metals and other pollutants were in fact making their way through the soil, then criteria would have to be made more stringent. The Division also could opt to evaluate the effectiveness of porous paving for the longer run and possibly undertake occasional sampling at a subset of sites, using the inactive monitoring wells.

It is anticipated that applicants may propose variations on this approach or even alternatives which are preferable from their standpoint. Alternative approaches should basically require that individualized loading studies be undertaken by the applicant in order to demonstrate comparable pollutant reduction performance. Evaluations might be done for each development, but such a recommendation would ultimately require that each applicant hire a special water quality consultant to undertake the necessary work. In fact, this Manual with continuing follow-up work is intended to take the place of this applied research. In concept, this Manual is to set out what must be done. In reality, anticipating the true complexity of the world and the many different permit contexts which will confront Division staff is a monumental task. It is certain that further refinements in the DCR program--both technically and institutionally--will be necessary.

Of paramount importance to this and other techniques is quality control--adherence to design specifications throughout the process of installation. In practice, accomplishing a higher degree of quality control usually means educating the contractor. If the contractor does not understand the significance of preventing sediment from washing onto the porous paved service, for example, chances are the problem is going to develop. If the contractor does not understand the importance of not compacting the base of the recharge bed, the probability is high that heavy equipment will be allowed to run over these beds and reduce their infiltration characteristics. Actually in the coastal drainage, the issue of compacting the sub-base is really turned upside down. Because the constraint here is usually excessive permeability, some installations might warrant compaction. It is recommended that an ongoing site inspection requirement be specified.

Finally, DCR staff should disregard recommendations made in the literature regarding maximum slope and site size criteria limits for porous paving. If properly designed and engineered, the porous paving/recharge bed BMP can be incorporated on sites of slopes far in excess of 5 percent (Figure 33), though obviously the actual surface of the porous paved beds should not exceed 3 percent slope. Similarly, the maximum site size of 10 acres, we believe, is completely ill-conceived. The rationale for this 10-acre maximum seems somehow to be related to the fact that larger sites generate more traffic activity and therefore will overstress porous pavement. If this is the rationale, then we strongly recommend that a more specific criterion be developed, relating directly to trips or weighted vehicle trips. Certainly very large commercial (office, retail, others)



SECTION THROUGH NEW PARKING LOT
Horizontal 1" = 30' Vertical 1" = 10'

Figure 33. Terraced Recharge Beds on Steep Slope (Cahill and Associates, 1985)

complexes can be (and have been) developed (Cahill and Adams, 1988) which utilize porous paving extremely efficiently. Its advantages can be just as compelling on a 50 acre site as on a 5 acre site.

Dual Purpose/Water Quality Detention Basins

As many authorities have stated, extending the detention time of a traditional detention basin designed simply to reduce peak rate of stormwater discharge usually is a relatively simple, straightforward, low-cost means of removing certain types of pollutants from runoff. This BMP is already in practice within the DCR. For paved area runoff where porous paving is not environmentally acceptable (i.e., where SHWT is not sufficient, combined with inadequate cation exchange capacity and non-residential land use), an alternative BMP must be selected. This alternative can be the dual purpose detention basin, also referred to as the extended detention basin. States Schueler (1987):

> "If stormwater is detained for 24 hours or more, as much as 90% removal of particulate pollutants is possible. However, extended detention only slightly reduces levels of soluble phosphorus and nitrogen found in urban runoff. Removal of these pollutants can be enhanced if the normally inundated area of the pond is managed as a shallow marsh or a permanent pool.
>
> "Extended detention ponds significantly reduce the frequency of occurrence of erosive floods downstream, depending on the quantity of stormwater detained and the time over which it is released. Extended detention is extremely cost-effective, with construction costs seldom more than 10% above those reported for conventional dry ponds."

Although irrelevant in tidally-dominated contexts, the advantage to the extended detention concept is that it can be incorporated into the same structure or facility which is required to mitigate peak rate reduction for the 2-, 10-, and 100-year storms. In such situations, all that is needed is a somewhat more elaborate outlet mechanism, guaranteeing that the water quality design storm (in this case, the 1-year 24-hour storm) or "settleability" storm is retained. Currently, NJDEP wants this storm to be detained for at least 18 hours, if the development is residential, and for 36 hours, if the development is nonresidential. The basic design concept is reflected in Figure 34. The Metropolitan Washington COG manual points out several design variations which can be employed to achieve extended detention, all of which represent some form of outlet control allowing only minimal discharge up to a design storage level (Figure 35):

- o a perforated riser enclosed in a gravel jacket
- o perforated extension of a low flow orifice, inlet controlled
- o perforated extension of a low flow orifice, internally controlled
- o slotted standpipe from low flow orifice, inlet control
- o negatively sloped pipe from riser
- o hooded riser

The latter two techniques are suggested for use with wet ponds or shallow marshes, illustrating that the extended detention concept can be integrated into wet pond and artificial wetland BMP's. Such approaches would actually be preferable from a nonpoint source water quality perspective, in that removal of solubilized and other pollutants would be accomplished as well. Given the added costs of the wet pond and artificial wetland approach, however, and the relative increase of the water quality benefit, we have not made use of these BMP's as primary recommendations. At the

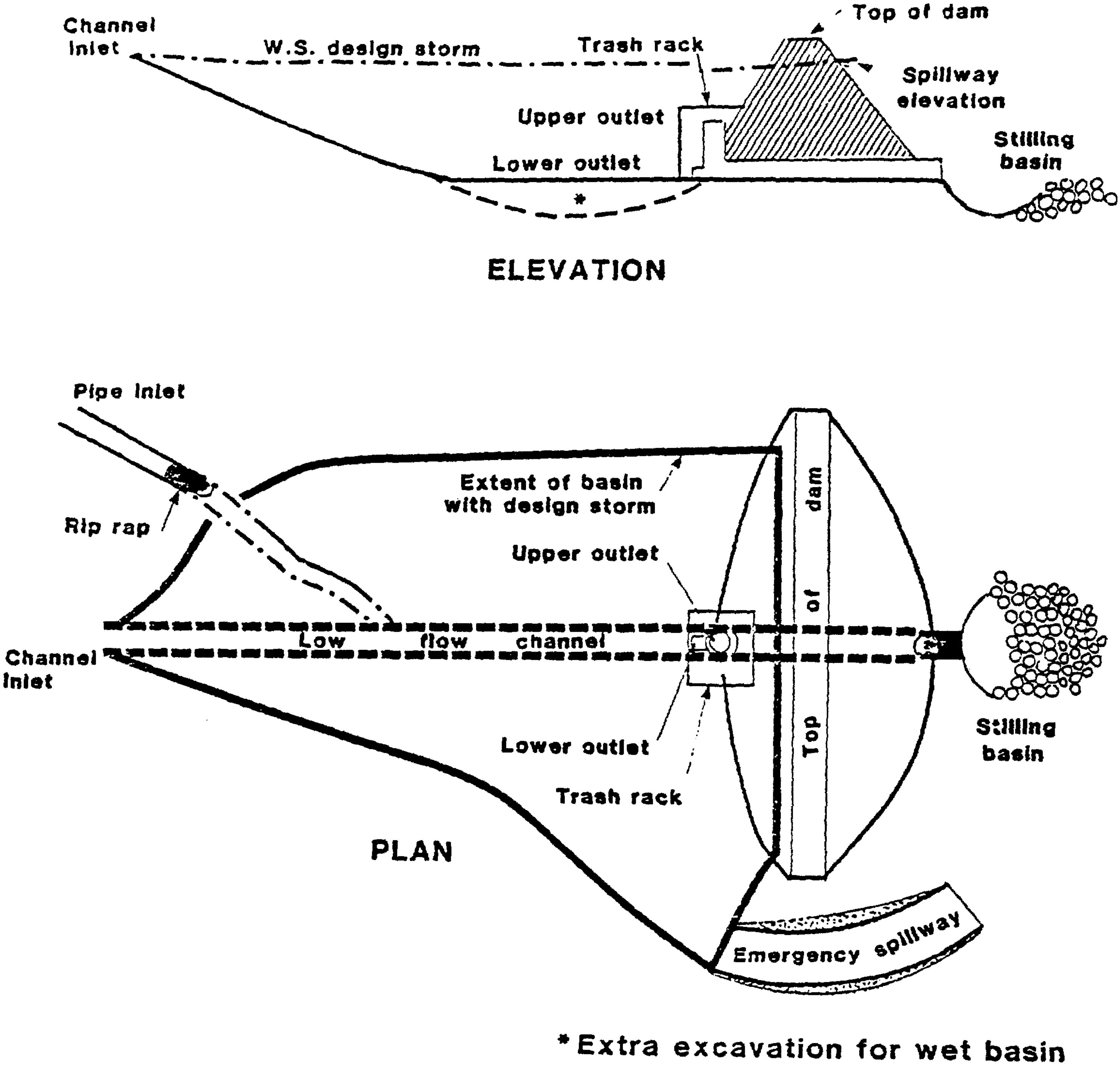
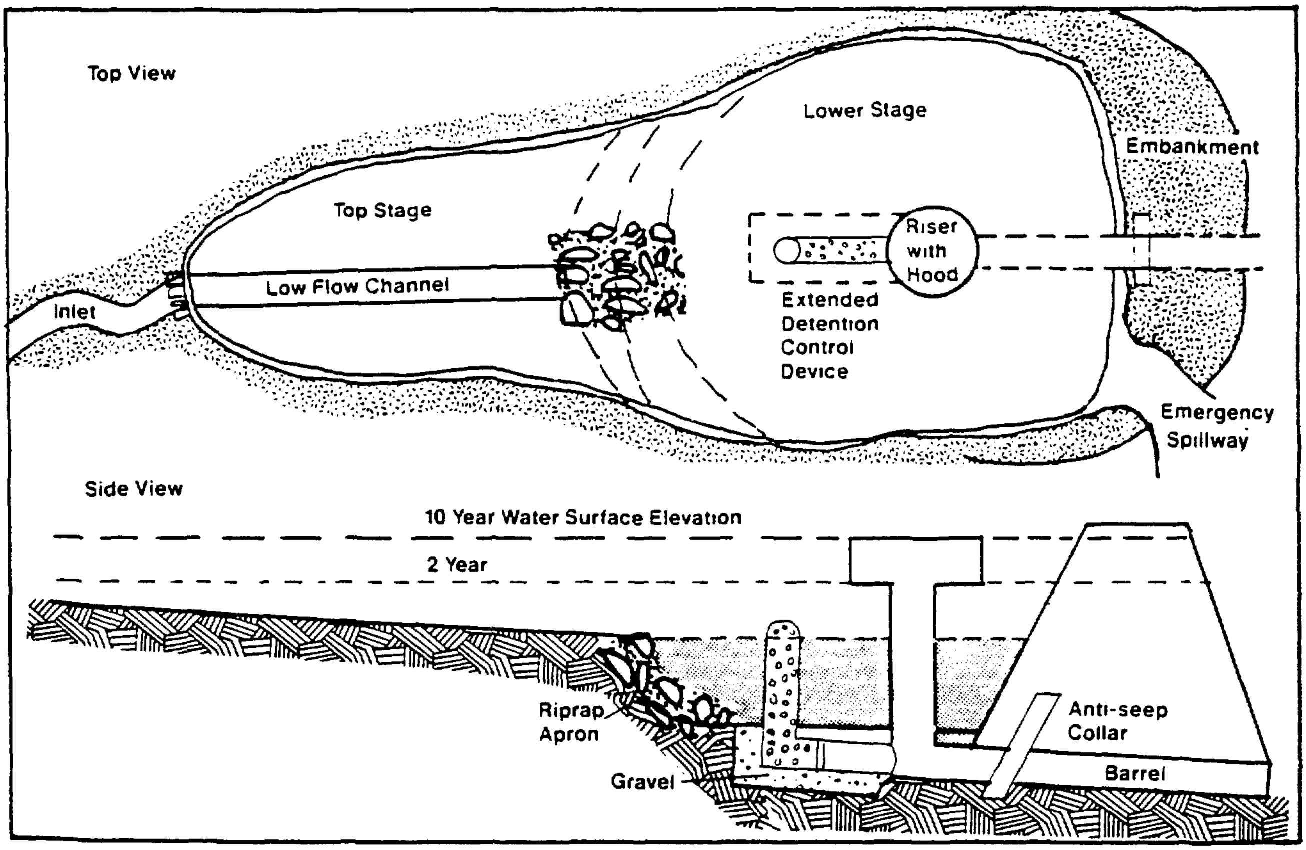


Figure 34. Plan and Profile of Dry Extended Detention Basin - NJDEP



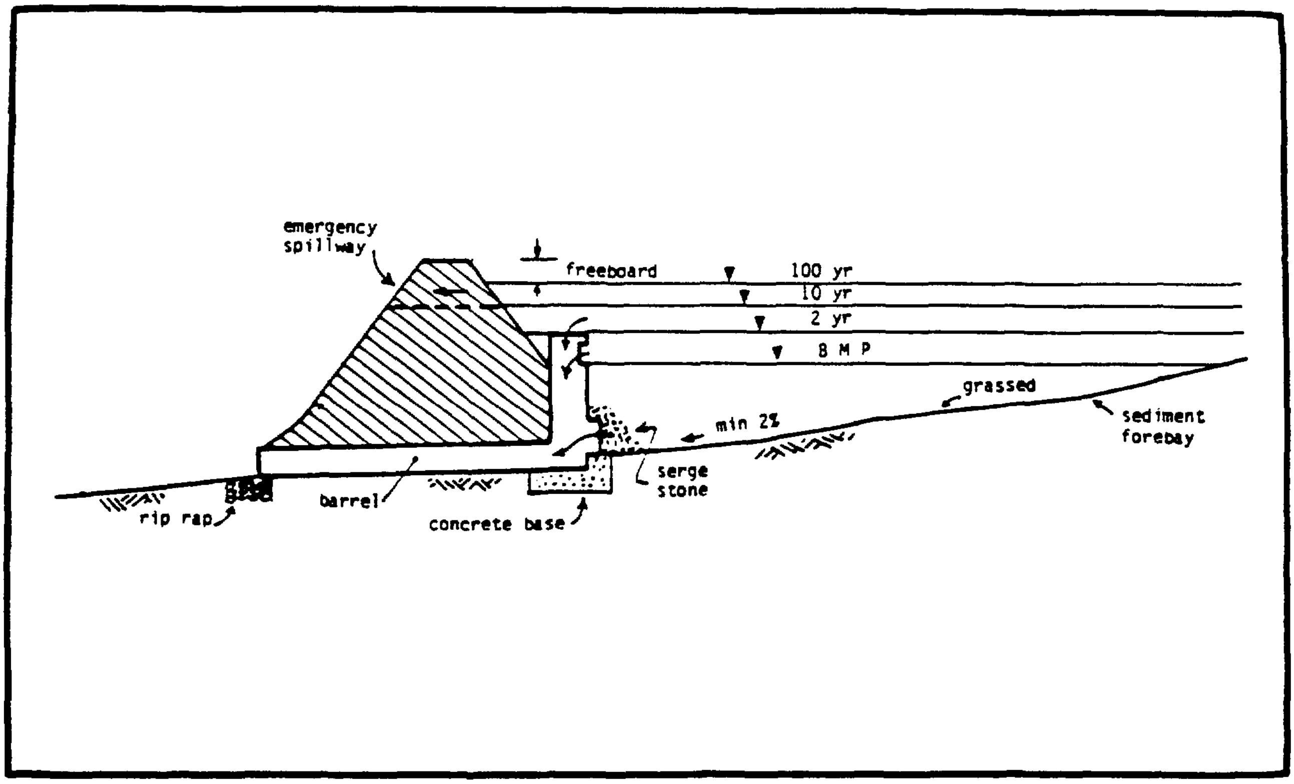


Figure 35. Plan and Profile of Dry Extended Detention Basin (Schueler, 1987)

same time, applicants should be encouraged to install wet ponds and artifical marshes wherever and whenever feasible.

A further variation on the extended detention or dual purpose detention basin pertains to applications within tidal situations where peak rate of runoff reduction for the 2-, 10-, and 100-year storms is made unnecessary. In these situations the "dual" purpose is eliminated and the only design objective is the water quality or settleability design storm. In such situations the size of the basin should be significantly reduced. This type of basin is referred to as the water quality detention basin.

Efficiency and Effectiveness

When compared to porous paving with recharge beds, dual purpose basins are not able to remove pollutants through cation exchange, chemical precipitation, or biooxidation by aerobic (and anaerobic) bacteria. Alternatively, dual purpose basins do allow for removal of sediment and other material which accumulates over time. On the one hand, paved area runoff should not be heavily laden with this type of material, assuming that paved and pervious surfaces are dealt with separately. On the other hand, to the extent that "real world" applications do not achieve their design, having this ability to remove settled material is an important advantage. As a matter of fact, we would make the qualification here in general that, if significant sedimentation or loadings of other particulate matter are anticipated for some reason (e.g., adjacency to large areas of exposed/disturbed sand) at a site, then a porous paving application, however preferable, may have to be avoided, given the sensitivity of the porous paving BMP to sedimentation problems.

As stated above, dual purpose detention basins are designed in concept for particulate matter. However, dual purpose basins also serve to remove substantial amounts of hydrocarbon loadings. Metals also are removed.

> "It is difficult to relate the characteristic biological degradation of urban streams to the pollution concentrations actually observed. In some cases, planned or unplanned releases of industrial waste may be responsible; but widespread similar degradation in non-industrial areas may be attributable largely to hydrocarbons. Hydrocarbons usually occur in concentrations of from 2 to 4 mg/l in urban runoff, mainly in particulate form, the remainder being dissolved (4). Although runoff from streets and parking lots has perceptible oil sheens on the surface, which are liquid in form, petroleum hydrocarbons are quickly sorbed on the particulates in runoff, so that storm sewers rarely contain hydrocarbons in liquid form unless substantial quantities have been spilled or deliberately released in the catchment area."
>
> "It has been estimated that this degree of retention will remove about 60% of the total suspended sediments in urban runoff, a similar proportion of the petroleum hydrocarbons, and lead, and perhaps 45% of the BOD, copper and phosphates."
>
> ("A Summary of EPA Research Findings on Stormwater Management," NJDEP, 1987b)

The essential idea behind the effectiveness of the dual detention basin is that runoff from the "first flush" be contained and slowly released, thereby capturing the bulk of the particulate matter as well as hydrocarbons adsorbed to these particulates. Settling column experiments have been conducted by Grizzard et al (1986), Driscoll (1986), and Whipple and Hunter (1981), demonstrating that 60 to 70 percent of urban sediments settle out within the first 6 hours, with maximum removal rates of 90 percent occurring after 48 hours. A study undertaken at the Stedwick dry pond in Montgomery County, Maryland for the Washington NURP work supported these findings, with 65 percent of the sediments settling out over the longer term. The Occoquan Watershed Monitoring Laboratory, in a study of another extended detention basin (London Commons) reported comparable 65 percent removal of sediments during 6 to 12-hour detention times (Schueler, 1987). Longer term settling of organic matter in the few studies which have been conducted is typically 40 percent or less. Some metals such as lead tend to settle out quickly; Whipple and Hunter found 90 percent removal in 48 hours with the bulk of that settling occurring within the first 6 hours. Zinc tends to be soluble, though it does sorb to other particles and then settle out, although Whipple and Hunter observed only 30 percent removal in their studies with the Occoquan studies at around 50 percent (Schueler, 1987)

Problems and Issues

Pollutants carried by storms larger than the settleability design storm (1-year, 24-hour storm) above and beyond the first flush would not be significantly reduced by this BMP. Nor would any type of pollutant not apt to settle (viz., most soluble pollutants such as nitrogen) be removed. Also, extended detention basins give rise to resuspension problems. By definition, if the basin is working, considerable material should accumulate on the basin bottom. If not removed by periodic dredging or excavation, this material will be resuspended during ensuing storms and can possibly lead to elevated loadings for major storm events larger than the design storm. Schueler recommends that basins have sediment removal performed every 5 to 10 years, depending upon the seriousness of the sediment problem in the area; monitoring data, including sediment accumulation measurement, will facilitate an efficient maintenance program.

On the other hand, the dual purpose detention basin has been shown to have secondary significant benefits in terms of down stream flooding (NJDEP, 1987b):.

> "For example, when a series of 400 detention basins were modeled, covering an 8000 acre main watershed, with each basin designed to control peak flow from 100-year, post development floods to the level of the 100 year pre-development peak at that site, the post-development peak flow at the outlet of the main channel was reduced by only 2%, and the two year and ten year peaks were reduced not at all. By contrast, a similar series of detention basins each designed to control particulate pollution from small floods, and to hold either a two, ten, or hundred year flood at site to its pre-development peak, reduced the post-development peak of hundred year floods of the main watershed by 20%, and the peaks of ten and two year floods by 24% and 44% respectively."

As other research has demonstrated, the traditional site-by-site approach to peak rate reduction, making sure that post-development peak rates of release do not exceed pre-development peak rates for the 2-, 10-, and 100-year storms, does not manage watershed-wide flooding. Even though this approach has been the practice in the State for some time and continues to be widespread, these design criteria most probably will lead to cumulative flooding effects downstream which can be potentially serious, as the synergistic effects of the increased volumes of runoff from post-development sites accumulate. This particular problem is the object of New Jersey's Phase II stormwater management planning program. Unfortunately, this Phase II program requires extensive watershed-wide modeling and is extremely time-consuming and expensive. It will be many years before all watersheds are properly modeled and all municipalities have integrated the necessary controls into their stormwater management ordinances. In the interim, the incorporation of the settleability or water quality design storm, pursuant to dual purpose detention basin design, has the important indirect benefit of reducing a considerable amount of this cumulative watershed-wide flooding impact, as the result of the delay of settleability design stormwaters.

Specific Directions

> **It is recommended that applicants employ dual purpose detention basins for impervious or paved area runoff in nontidal situations where soil renovating capacity is inadequate (i.e., where the SHWT is less than 12 inches, regardless of the type of proposal, or where the SHWT is between 12 and 48**

inches with a soil cation exchange capacity of less than 10 for nonresidential proposals). In tidal contexts, the recommendation is the same, except that the dual nature of the basin may be obviated and only the 1-year, 24-hour water quality design storm need be accommodated, assuming tidal dominance. The existing NJDEP design criteria of retaining this storm such that 90 percent of the detained water drains out of the basin in no less than 18 hours for residential developments and no less than 36 hours for nonresidential developments are relevant here, although we would urge NJDEP to undertake re-evaluation of these criteria to, for example, 24 and 48 hours, based on the research findings which have been reviewed during the course of Manual preparation. While not mandatory, wet ponds and artificial wetlands should also be seriously considered in concert with this extended detention technique, in order to perform more complete pollutant removal. In some cases, these wet ponds may be the only feasible approach, if the water table is at or near the surface.

Infiltration Techniques

Infiltration techniques come in a variety of BMP designs. Infiltration basins (Figure 36), infiltration trenches (Figures 37 through 39), and infiltration wells or dutch drains (Figure 40) are three typical configurations, although there are innumerable variations on these configurations. Furthermore, infiltration devices can be incorporated into other BMP techniques. Some multiple chamber catch basins provide infiltration, for example. Porous paving with recharge beds obviously relies substantially on infiltration, though it has been treated as a separate BMP here. Infiltration also occurs to some degree in other techniques, though not as their primary function or objective. For example, some infiltration can be expected to occur in dual purpose detention basins and wet ponds, though certainly not to the degree that is designed into infiltration devices.

Theoretically, infiltration devices are intended to accomplish the same sort of pollution removal functions accomplished by porous paving and recharge beds. Reliance here is on the natural renovating capabilities of the soil mantle, cation exchange, action by aerobic (and anaerobic) bacteria, physical filtering of particulates, chemical precipitation, and the like. Application here is set out in the form of a secondary recommendation for runoff from pervious or lawn areas and assumes that our primary recommendation of zero maintenance is not pursued for some reason. If this is the case, then it is of paramount importance that the nutrient loadings from fertilizer applications, pesticides, and herbicides be reduced in some manner. Removal can most effectively be accomplished by infiltration through the soil, if an adequate soil mantle exists. Presumably, infiltration techniques would be used in situations where porous paving and recharge beds were used for pavement runoff (again where minimum disturbance/minimum maintenance had been rejected for some reason) and would be the mechanism used to handle runoff from the non-paved areas. Infiltration techniques provide a way to accommodate pervious runoff which must be kept distinct from porous pavement.

In the relatively brief history during which infiltration techniques have been used, a major concern for many engineers has been ensuring that the infiltration capability of the soil is not negatively affected during the construction process. Often this problem has developed as the result of operating heavy equipment over areas to be used for infiltration, resulting in excessive compaction of the soils and the consequent failure of the recharge bed to adequately exfiltrate. Ironically, within most of the coastal drainage, we are confronted with soil conditions with excessively high rates of percolation, which then becomes the limiting factor and prevents the use of recharge

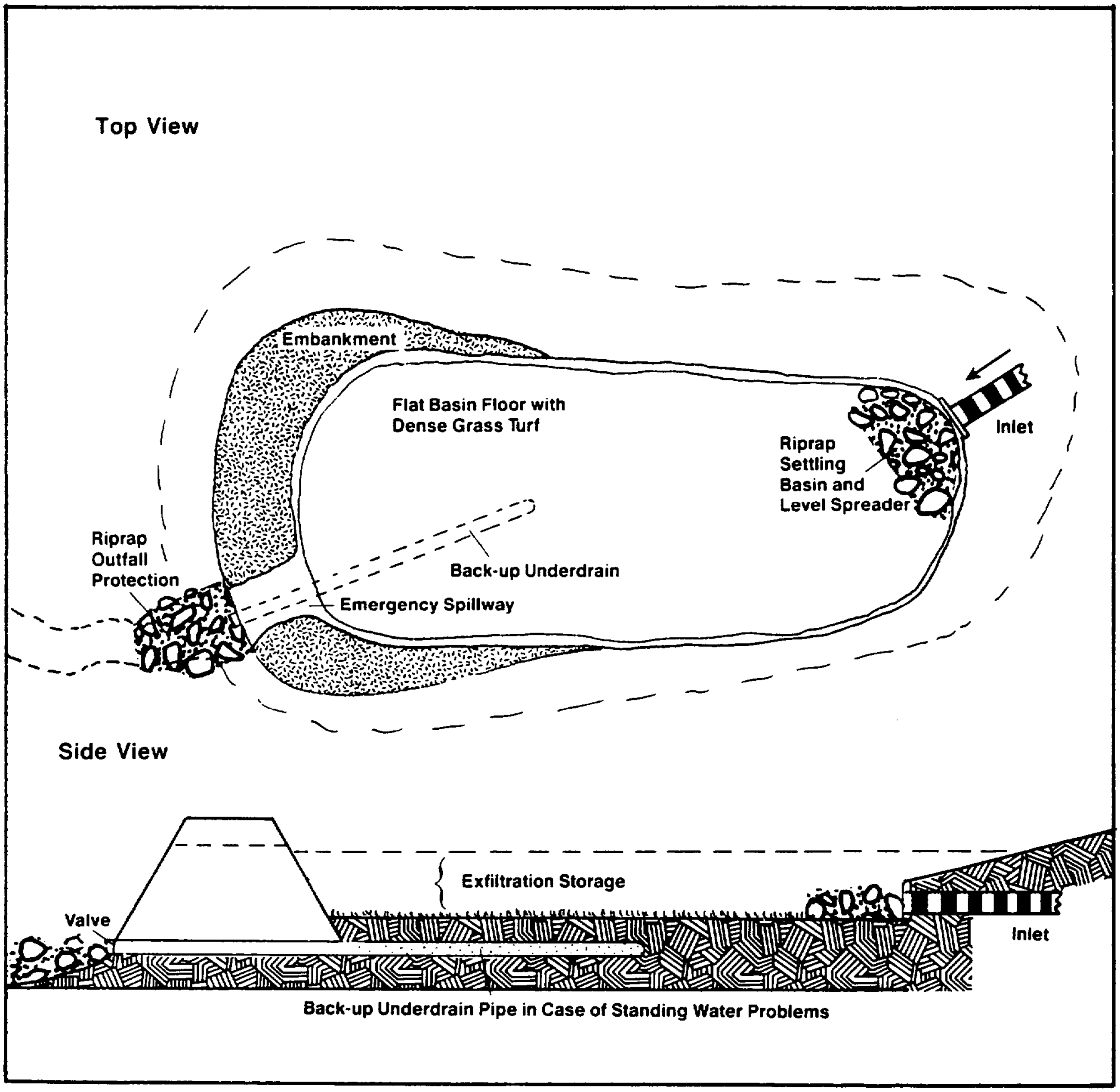


Figure 36. Diagram of an Infiltration Basin (Schueler, 1987)

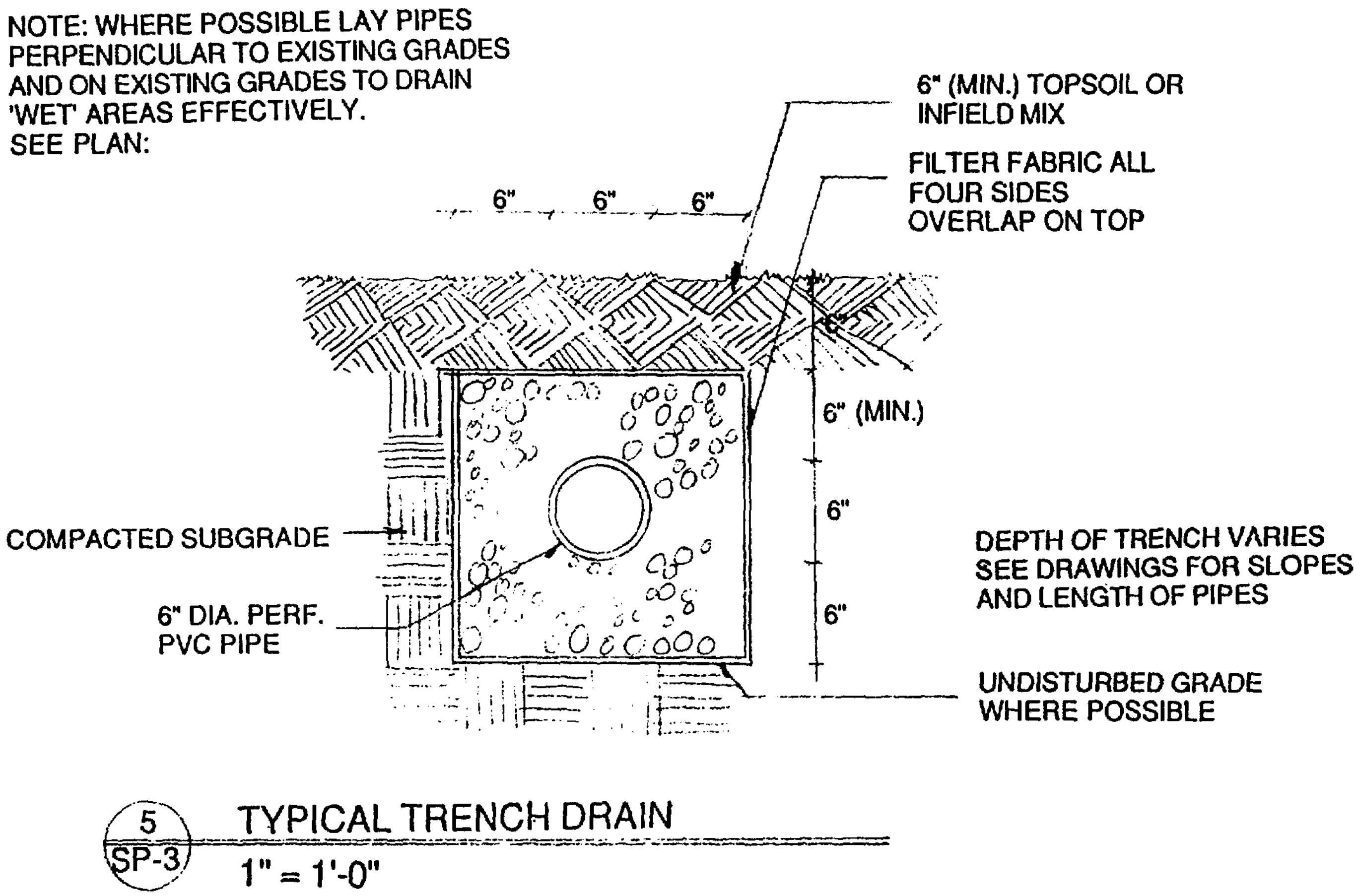


Figure 37. Diagram of an Infiltration Trench (Cahill and Associates, 1985)

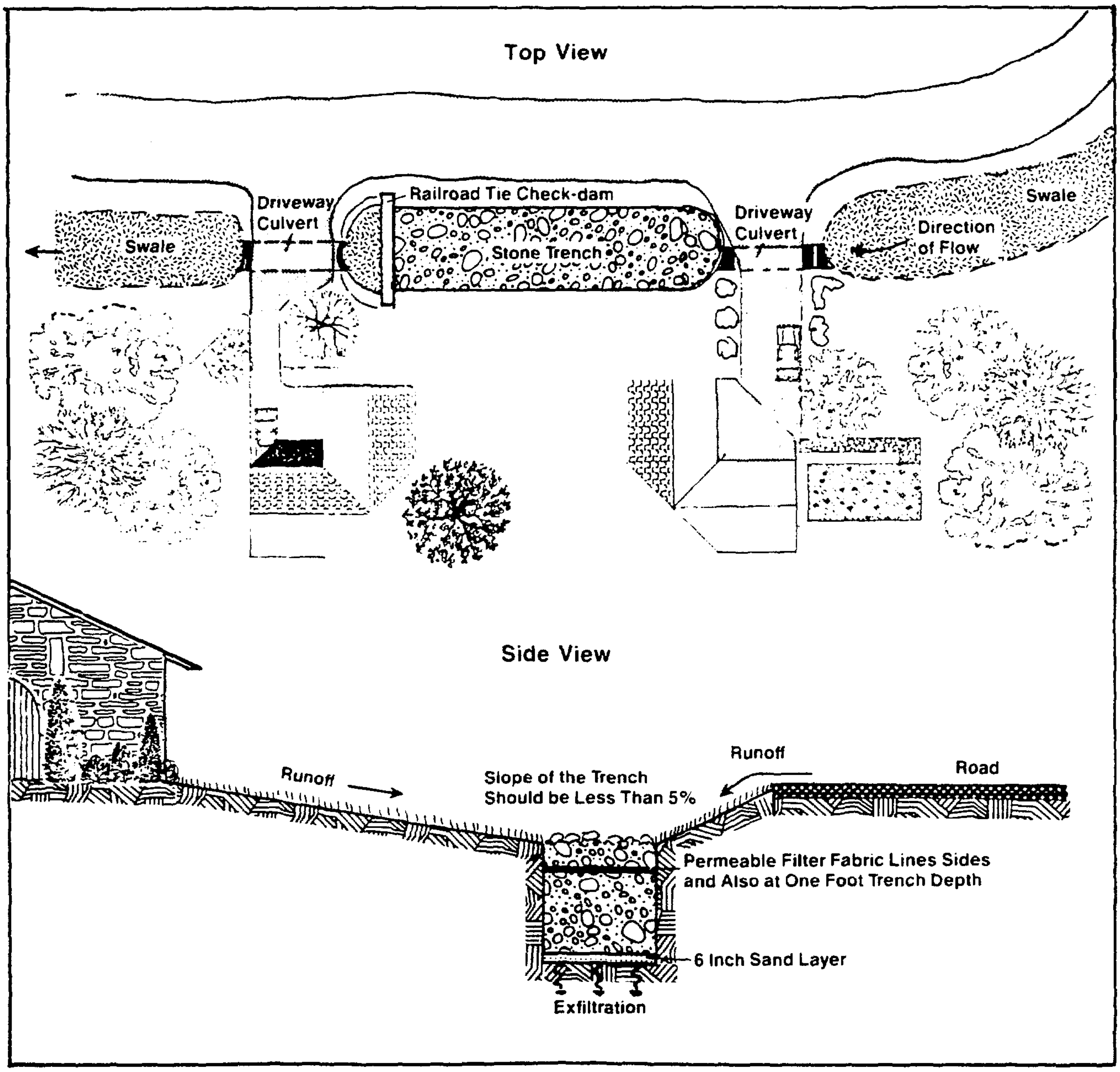


Figure 38. Design of Swale/Trench (Schueler, 1987)

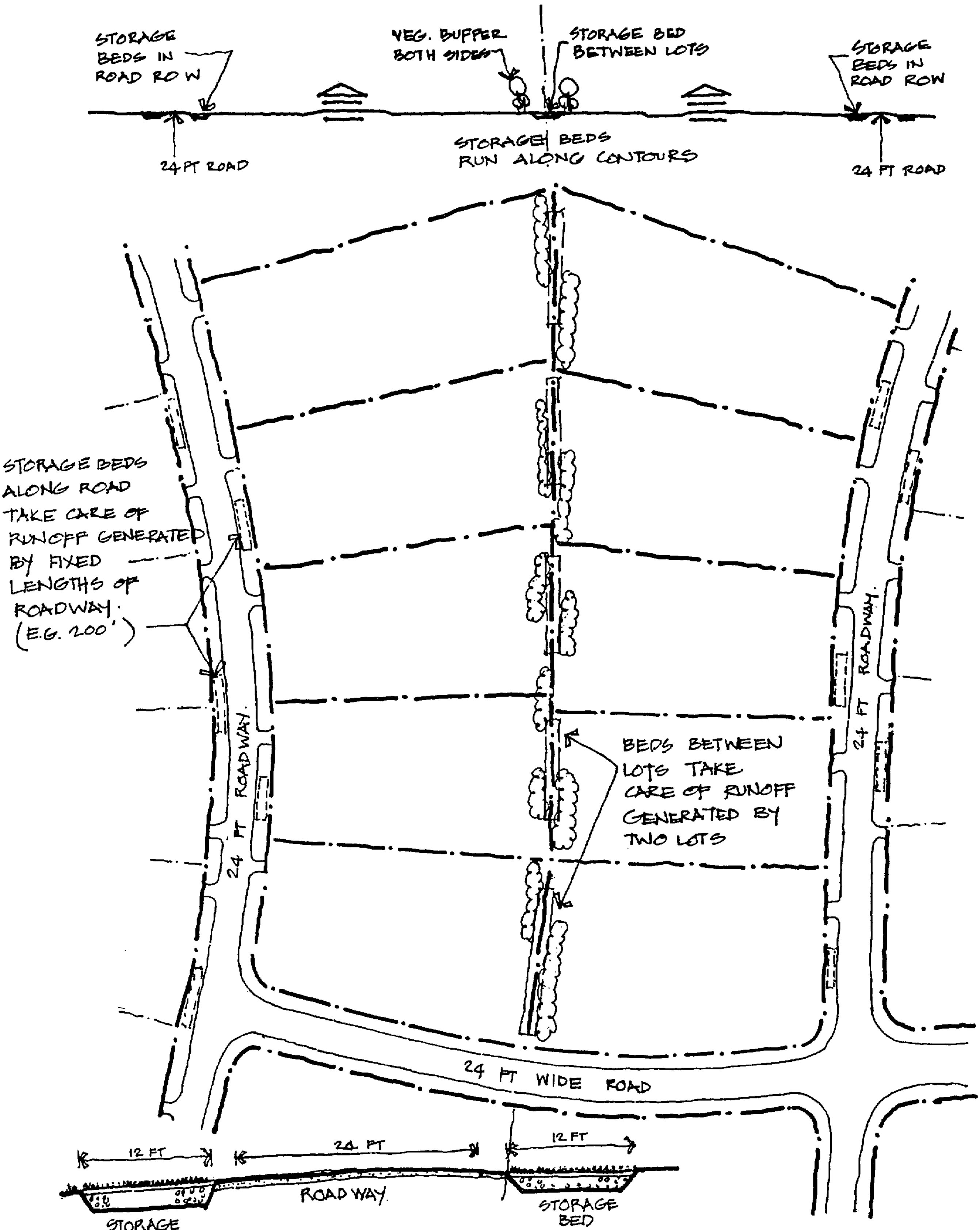


Figure 39. Lot Grading Plan for Infiltration Trench Application (Cahill and Associates, 1988)

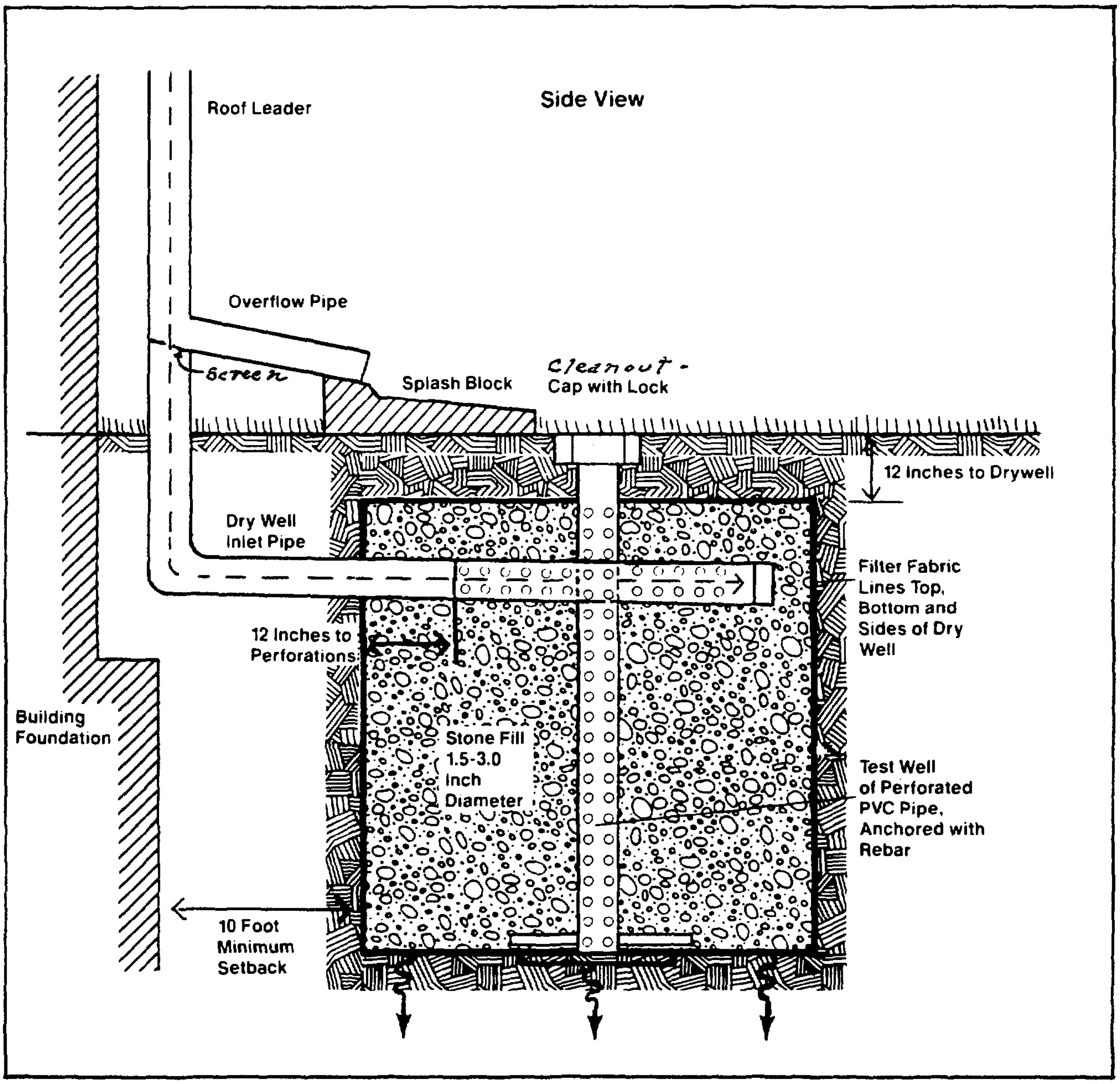


Figure 40. Dry Well Design (Schueler, 1987)

systems. Therefore, intentional compaction may be appropriate in order to enable broader application of recharge systems. NJDEP should sponsor research into this question.

The most straightforward approach to infiltration is the infiltration basin (Figure 36), to be used obviously in areas with permeable soils. Basins must (Schueler, 1987):

> "1. Trap excess loads of coarse grained sediment before they enter the basin and clog the surface soil pores on the basin floor.
>
> 2. Route design stormflows through the basin without scouring or eroding the basin floor.
>
> 3. Route baseflow (if any exists) rapidly through the basin to prevent ponding or standing water.
>
> 4. Distribute storm runoff volume evenly over the floor of the basin to maximize exfiltration rates.
>
> 5. Provide a back-up drainage system, should the infiltration capacity of the basin fail."

Schueler suggests that the infiltration basin be designed for the 2-year storm; if space allows, the capacity can be expanded to include detention capacity for the larger design storms (up to the 100-year storm), although if these flows are to be included, care should be taken to make sure that runoff as it enters the basin is trapped in a riprap settling basin where coarse sediment drops out. Additional variations include the side-by-side basin (Figure 41), where a riprap channel is constructed along one margin of the basin and extends to a riser, an off-line infiltration basin (Figure 42), where the first flush runoff volume is diverted and exfiltrated, and the combined infiltration/detention basin (Figure 43). States Schueler (1987):

> "Off-line designs are used to divert and exfiltrate the first flush runoff volume from a storm sewer or surface channel. They are particularly useful in development situations where exfiltration cannot be achieved by a downstream stormwater detention facility due to soil limitations. An off-line design modified from the City of Austin DPW (1986) is shown in Figure....This design utilizes a combination of an off-line sand filter and infiltration basin to treat the first flush volume. A weir is placed across a natural or man made channel that diverts runoff into an off-line sand filter. After percolating through the sand filter, runoff is collected by underdrains which lead to a level, vegetated infiltration basin. This is a particularly appropriate design for sites that drain land uses which produce high sediment or hydrocarbon loads."

Infiltration trenches are a design variation of infiltration basins, where basically the same pollutant removal mechanisms are being relied upon, and where the same constraints regarding the natural renovating capability of the soils must be respected. According to Maryland's Inspector's Guidelines Manual for Stormwater Management Infiltration Practices, infiltration trenches usually consist of a long and narrow excavation, from 3 to 12 ft in depth, filled with stone aggregate. Trenches as a linear feature sometimes can be more readily incorporated into site design, paralleling property or building lines where minimal space is available and a basin per se would not be feasible. In such situations, the quantity of water received typically would be less for a trench than for a basin, and therefore the drainage area would be more limited. Of course, the extent of trenches in a site design can conceivably grow to be substantial, depending upon the particular design. Schueler points out that infiltration trenches may be designed for complete or partial exfiltration and may be on the surface (e.g., a median strip design, parking lot perimeter design, or swale design) or below the ground (e.g., an over-sized pipe trench, an underground trench with an oil-grit inlet, an under-the-swale design, and an off-line trench). In any one situation, the site engineer should determine what particular infiltration technique or what combination of techniques

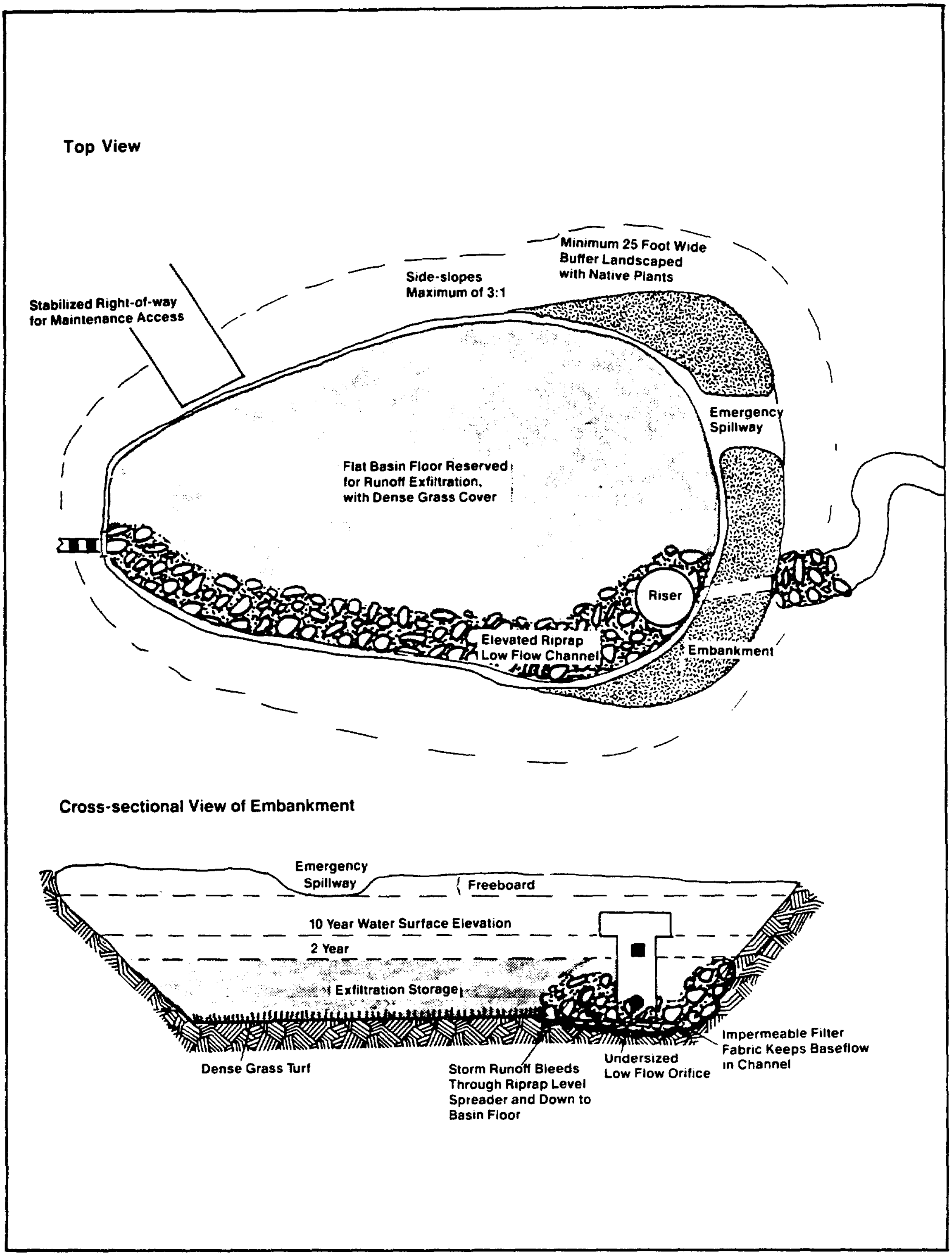


Figure 41. Side-by-Side Infiltration Basin Design (Schueler, 1987)

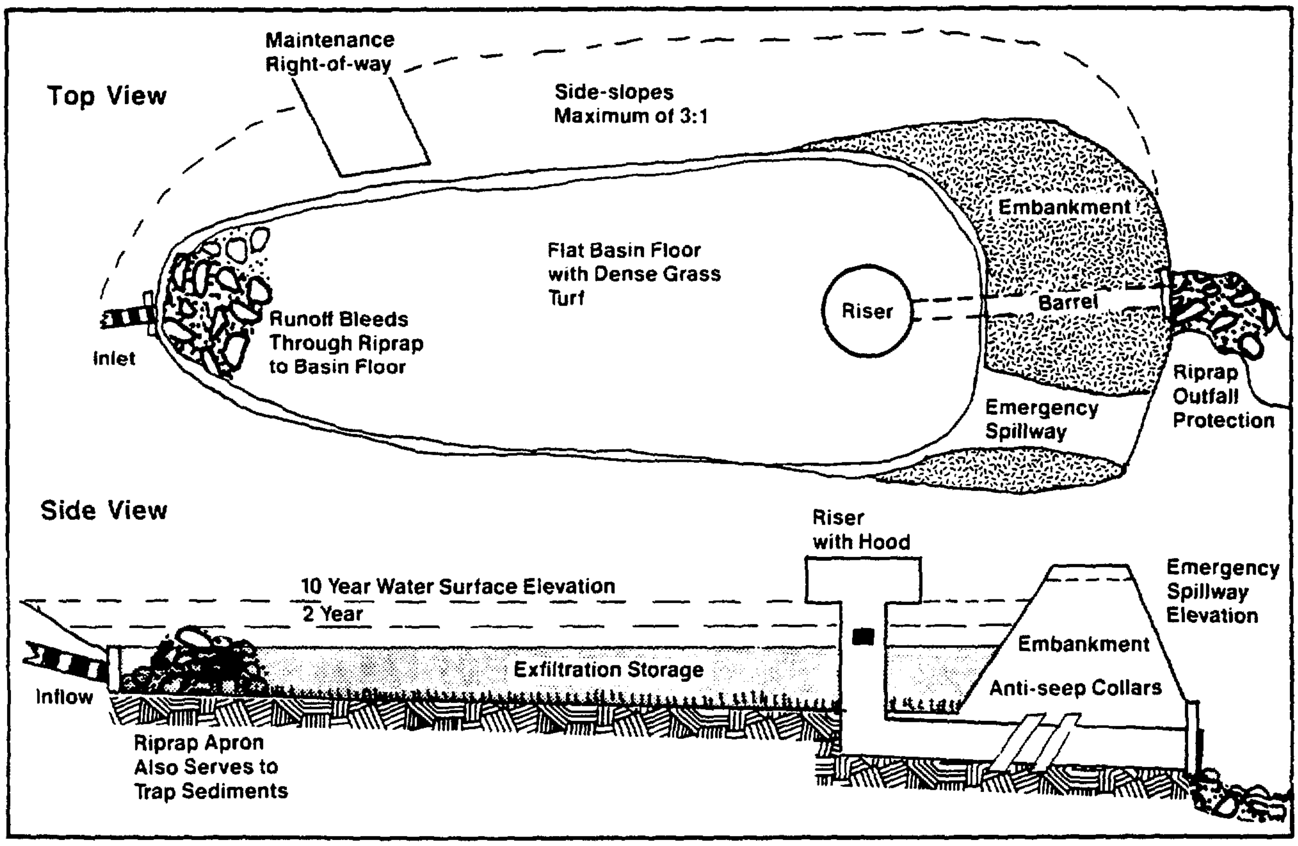


Figure 42. Off-line Infiltration Basin Design (Schueler, 1987)

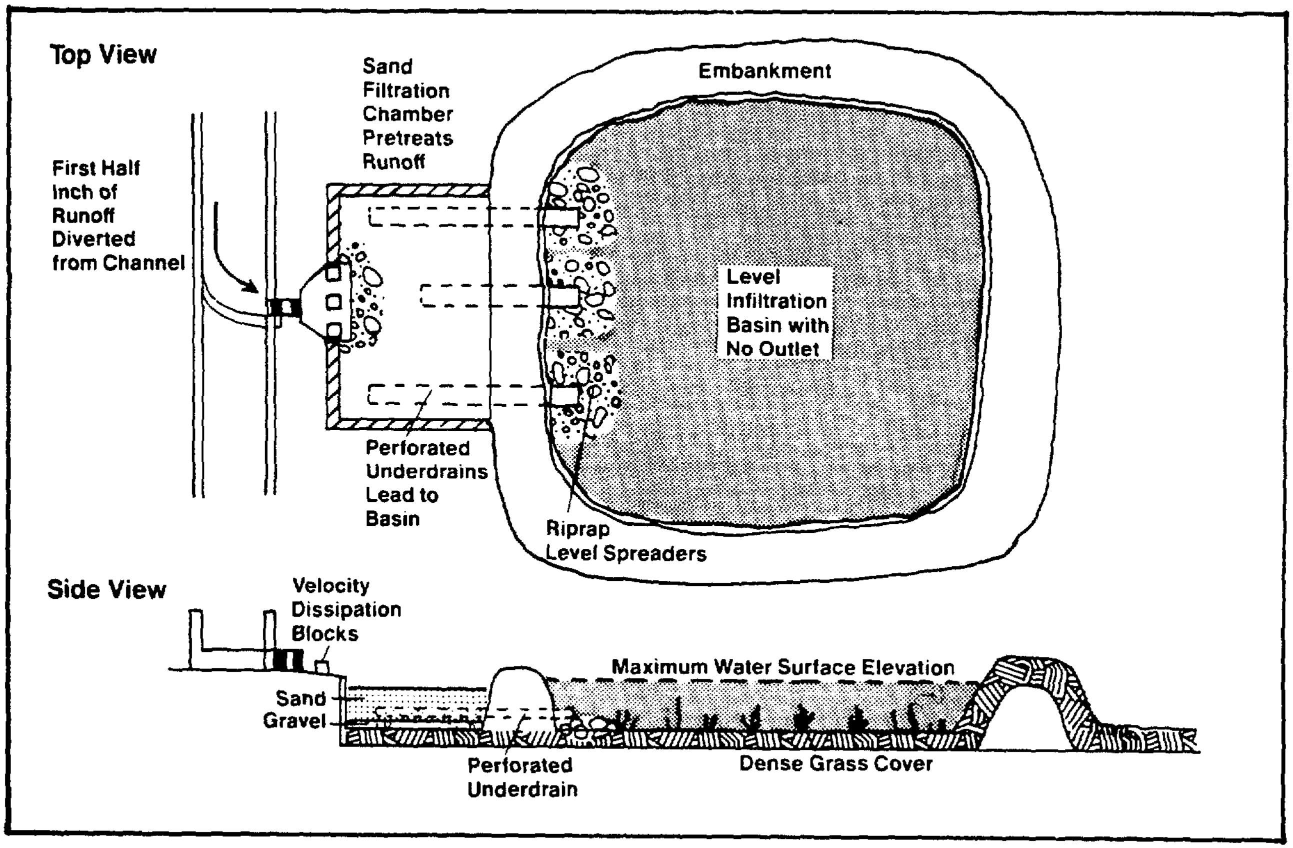


Figure 43. Combined Infiltration/Detention Basin Design (Schueler, 1987)

should be employed. Quite probably, the most cost-effective solution in any specific case will require an array of types of basins and trenches and dry wells, as discussed below. Trenches normally should be buffered by areas of natural vegetation, the denser the better. Various measures will have to be taken to guarantee that the trench inlet(s) do not become filled with sediment during and after construction and that debris is kept free of the trench so that clogging does not occur.

Dry wells or dutch drains are a further variation on the infiltration theme, typically used in applications where quantity of runoff is not great. Again, the theory behind the dry well's operation is exactly that of the infiltration basin or trench, and therefore the standards are similar. The major exception here is for adaptation for roof runoff where pollutant loadings can be expected to be modest and where soils constraints can be relaxed. Dry wells per se will probably not receive wide application in non-tidal situations because of their limitations in terms of quantity. Theoretically, use of the maximum number of recharge points through multiple dry well locations distributed in a residential subdivision, for example, would be environmentally preferable. In reality, however, this highly individualized approach may be cumbersome and actually more costly than other combinations of trenches and basins strategically located.

Efficiency and Effectiveness

Under correct conditions, pollutant removal capabilities of infiltration techniques are excellent. Schueler (1987) reports remarkably high pollutant removal percentages for infiltration basins, if the 2-year design storm is used:

sediment	99 percent
total phosphorus	65-75 percent
total nitrogen	60-70 percent
trace metals	95-99 percent
BOD	90 percent
bacteria	98 percent

Pollutant removal effectiveness for infiltration trenches and dry wells is estimated to be nearly as great as those for basins, assuming that the appropriate planning and engineering standards are used. The State of Maryland recently released a study, reporting on a survey of infiltration practices throughout the State, which found that the infiltration trench was both the most common form of infiltration BMP being used in Maryland and that it was also the most successful in its application. Furthermore, the State researchers discovered that well over half of the non-working trenches had been developed without the aid of any soil borings, some had been developed without any sort of natural buffer or filter strip, and some had been developed without observation wells (i.e., improper installation was responsible for most of the failures).

As with minimum disturbance/minimum maintenance and porous paving/recharge beds, infiltration mechanisms significantly increase groundwater recharge and therefore also provide substantial stormwater volume control. In terms of total watershed-wide flooding effects, infiltration BMP's are very effective, because they offer the potential for volume reduction as well as attenuation of the peak of stormwater releases. Streambank erosion is thereby minimized. As the result of recharge, the overall effect should be to enhance baseflow of streams, although in much of the coastal drainage this particular concern may not be especially relevant.

Specific Directions

Infiltration devices, including basins, trenches, wells and variations thereof, are recommended here as secondary or back-up BMP's to be used for pervious area runoff control. Lacking the ability to use our primary

recommendation of minimum disturbance/minimum maintenance, these infiltration devices offer the greatest potential for removing nonpoint source pollutants from stormwater. In the tidal context, infiltration BMP's should be used for pervious area runoff where soil renovating capacity is adequate (i.e., where SHWT is at least 48 inches or where SHWT is 12 to 48 inches and where cation exchange values are greater than 10). In this particular case, we do not differentiate by land use type, as we expect the pervious portion of all types of land uses here to be receiving the same sorts of fertilizers, pesticides, and herbicides. As a matter of fact, in all too many instances, the same chemical application trucks perform the same services on commercial and office parks as they do within residential areas. Of course, in the tidal context, flood peaking concerns are less relevant, possibly irrelevant.

For nontidal situations, the same conditions regarding soil limitations apply. In these cases, however, runoff quantity is an issue and must be designed for so that peak rates of runoff for the 2-, 10-, and 100-year storms are not increased. It should be noted here that incorporating this quantity consideration into design of the infiltration BMP could be relatively expensive. It may be more cost-effective to increase peak rate attenuation capability of the paved area runoff BMP. At least this flexibility should be allowed.

Finally, we recommend infiltration BMP's, most probably in the form of dry wells, to receive roof runoff in virtually all situations. There are no soil limitations here, as we expect this roof runoff to be relatively free of pollutants, other than those coming from atmospheric deposition. Therefore conveying this runoff directly into the groundwater, even with questionable renovating capability, should pose no problem. In tidal contexts, the dry well would be designed for the high frequency storm (i.e, 1- or 2-year storm) and would not have to accommodate larger storms (excess from the 10- or 100-year storms could literally be direct discharged into tidal waters, if convenient). In nontidal contexts, the issue of increase in peak rate of runoff for the 10- and 100-year storms must also be calculated for rooftop runoff and taken into consideration quantitatively somewhere on the site. This liberalization of the soil constraint criterion should not be allowed in those situations where increased pollutant loadings are expected. Though difficult to assess in advance, significant bird roosting with consequent bird droppings can result in loading difficulties. In these or other unusual situations (e.g., industrial facility roofs), this polluted rooftop runoff should be directed into the artificial wetland or wet pond if being planned. If soils are adequate, the dry well or any other infiltration BMP being planned is acceptable for use.

Artificial Wetlands and Wet Ponds

Artificial wetlands (Figures 44 through 46) and wet ponds (Figures 47 through 49) are grouped together here because of the similarity in their basic pollution removal mechanisms. In both cases, biological uptake is added to the list of pollution removal functions, although in the case of wetlands, that function is accomplished through uptake by macrophytes, plankton, and periphyton. In wet ponds, the functions are accomplished predominantly by algae. Although there is a proliferation of books and manuals emerging on wetlands, wetlands mitigation, and wetlands creation these days, we would recommend the State of Maryland's research, sponsored jointly with the University of Maryland, as reported in *Wetland Basin for Stormwater Treatment: Analysis and Guidelines Final Report* by Athanas (1986). In all contexts, we have reserved these techniques as secondary recommendations because of the complexity and costs associated with their implementation. We strongly urge that applicants be directed to employ minimum disturbance/minimum maintenance approaches. However, if for some reason this recommendation is not embraced, if traditional approaches to site disturbance and site landscaping and maintenance must be used, and if the natural soil renovating capacity of the site soil mantle is not adequate, then artificial wetlands or wet ponds must be used, as these BMP's are the only methods able to effectively remove the excess nutrients from the aquatic system. The term "remove" must be used carefully, because true removal from the system may require biomass harvesting of macrophytes as well as algae removal during peak growth periods, two processes which can be both difficult and expensive. This is a radical requirement which will trigger resistance from many in the development community. However, if further change within this particularly fragile coastal ecosystem is to be allowed, then this development must be made to conform to more thoroughgoing standards.

As Athanas points out, the ideal artificial wetland is a shallow wetland with heavy vegetation, with only about 25 percent of the total wetland area actually in open water (Figures 50 through 52). Inflow totals must exceed infiltration. Interception with the groundwater is not a problem and can assist in the total wetland operation. In extreme cases where infiltration is rapid and maintaining any sort of permanent pool is impossible, a clay or plastic liner can be installed first, although this is an extreme situation (given our coastal context, if the water table is presumably that deep, then infiltration techniques should be the preferable BMP approach anyway). Wetland surface area should be maximized. States Athanas (1986):

> "...shallow water (i.e.,< 30 cm) promotes the growth of most species of emergent vegetation. Since emergent vegetation is likely to contribute to the pollution removal capability of the wetland, and certainly contributes to its value to wildlife, the water at the wetland should be at depths conducive to the growth of emergent vegetation."
>
> "In general, approximately 75% of the wetland should have water depths less than 30 cm, and 25% of the wetland should have depths ranging from 60 to 91 cm. The deeper depths will, for the most part, result in open water, which will make the entire wetland more attractive to waterfowl (waterfowl seem to prefer a habitat with both cover and open water (Weller 1978). In addition, the deeper water will favor the growth of submerged aquatic vegetation, another food source for waterfowl."
>
> "The deeper area of the wetland should include the outlet structure so that outflow from the basin is not interfered with by sediment buildup. Having the outlet at the surface of a 60 or 91 cm pond means that a considerable amount of sediment build-up can occur before outflow is blocked."

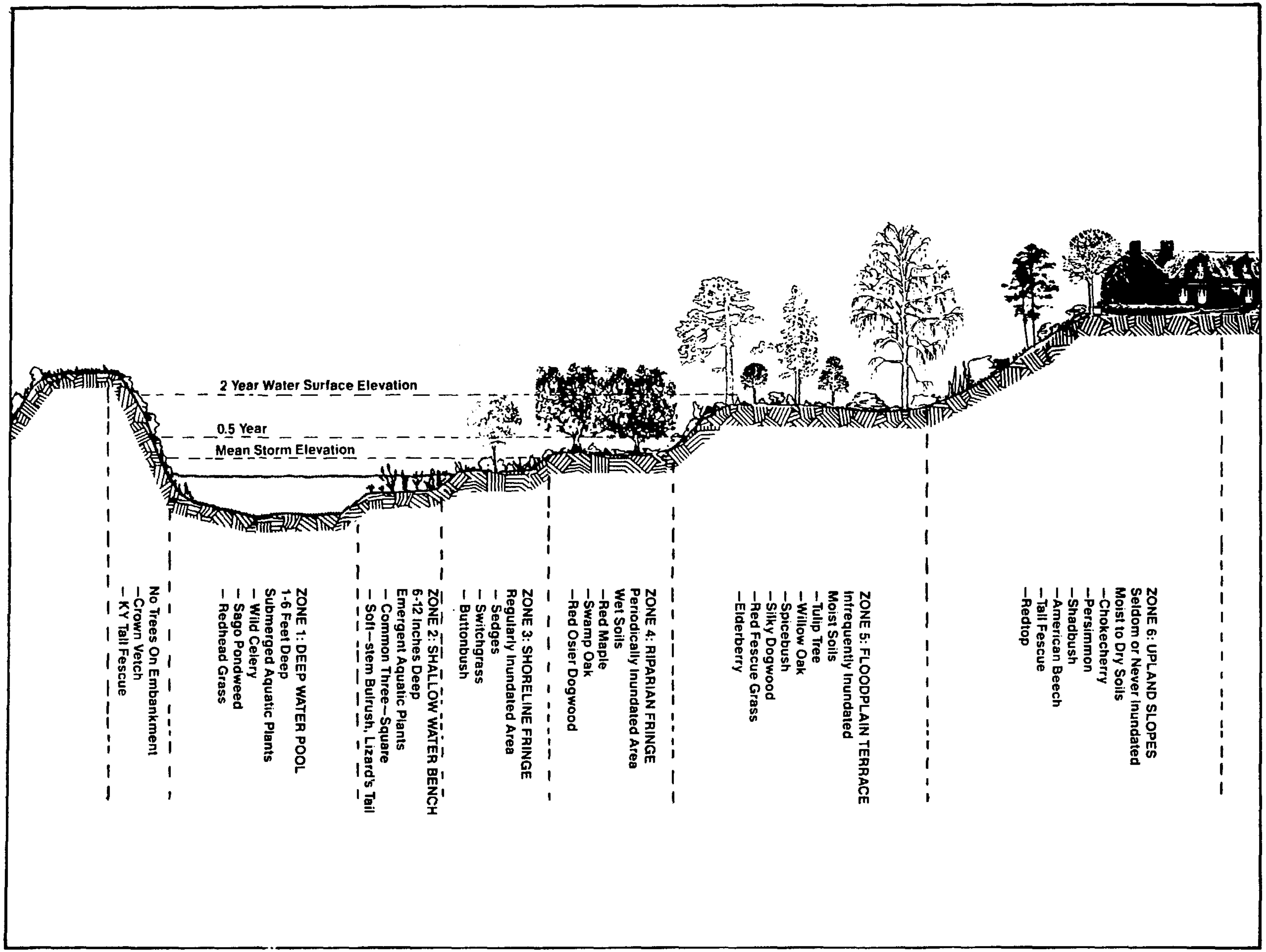


Figure 44. Vegetative Best Management Practices Scheme (Schueler, 1987)

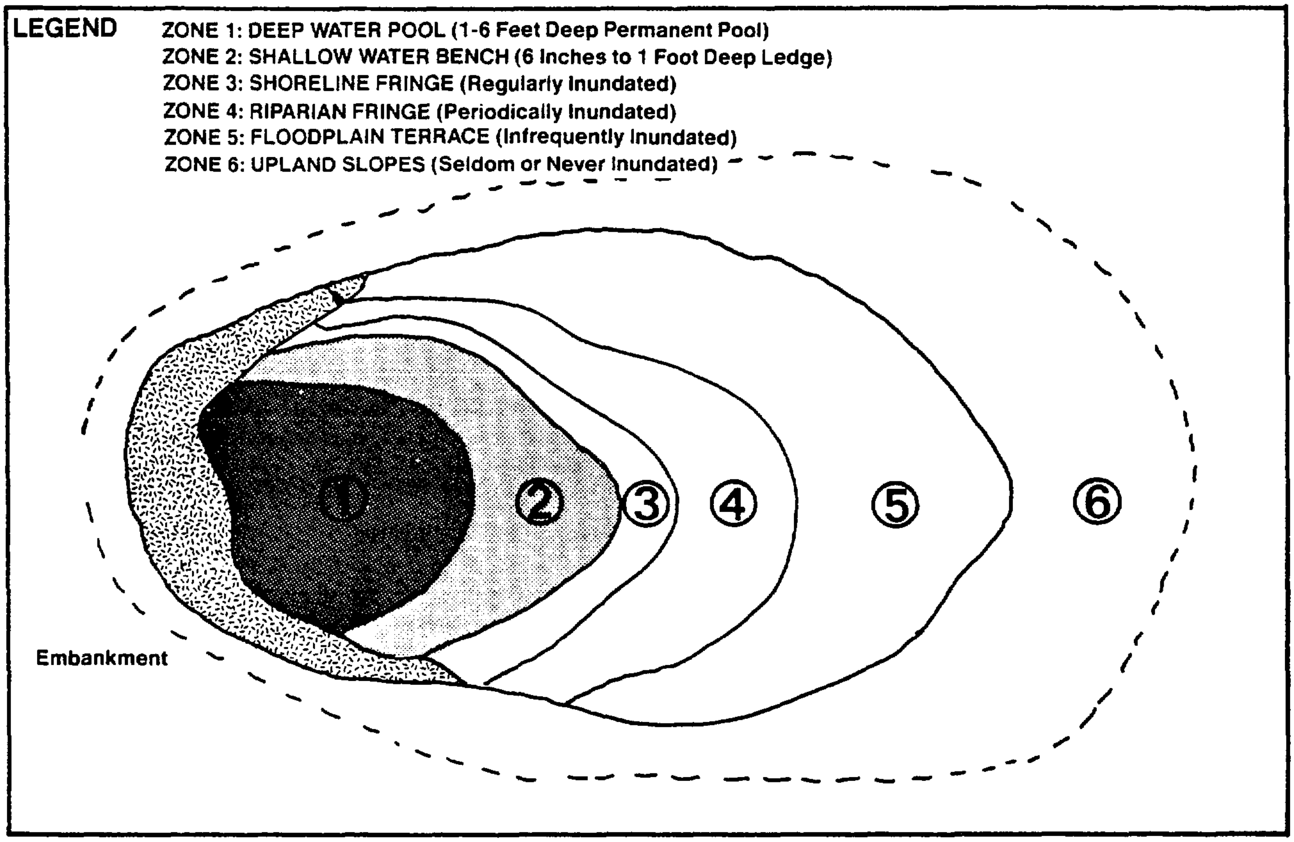


Figure 45. Illustrative Design of a Created Wetland (Schueler, 1987)

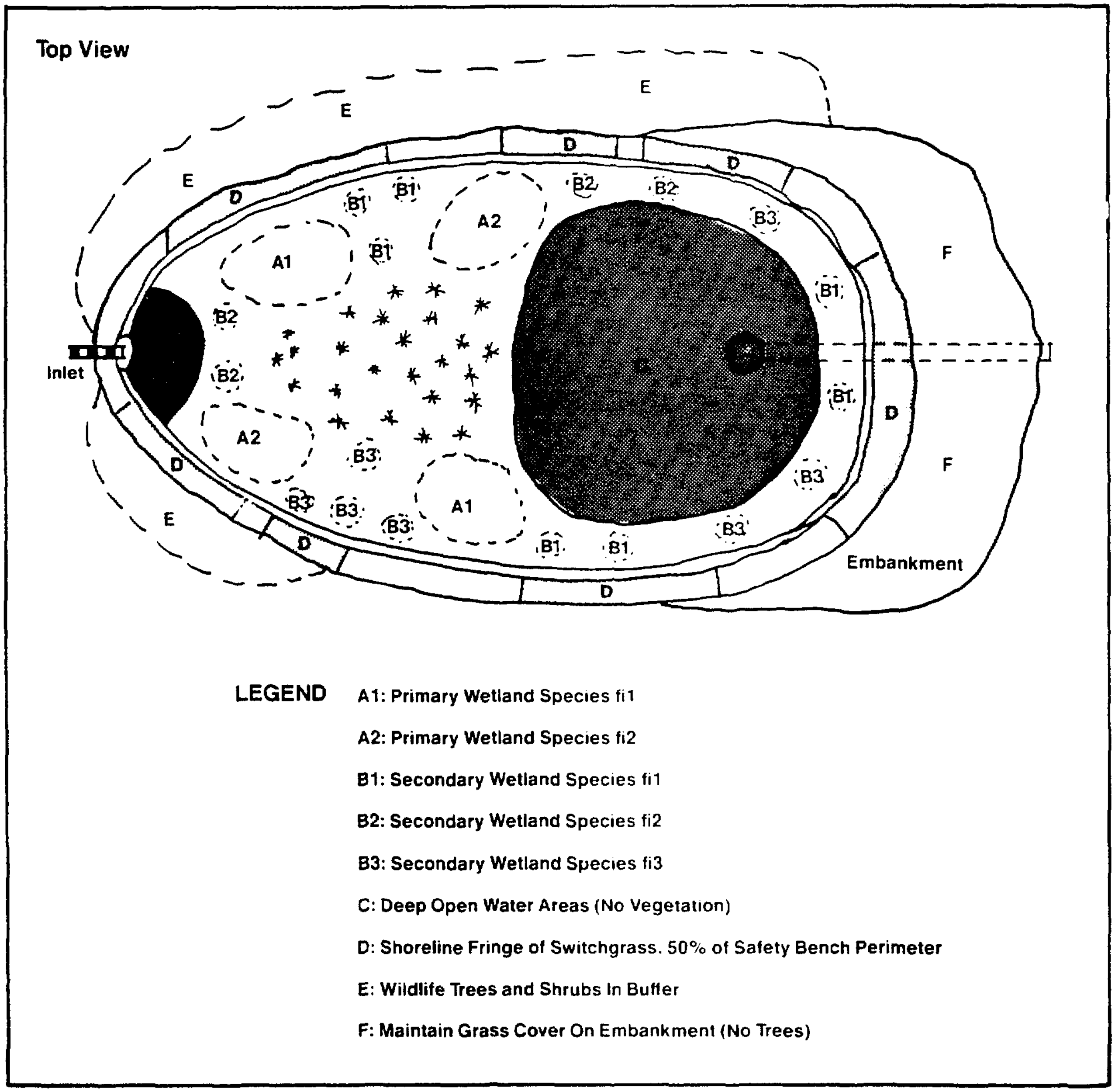


Figure 46. Recommended Basin Planting Key (Schueler, 1987)

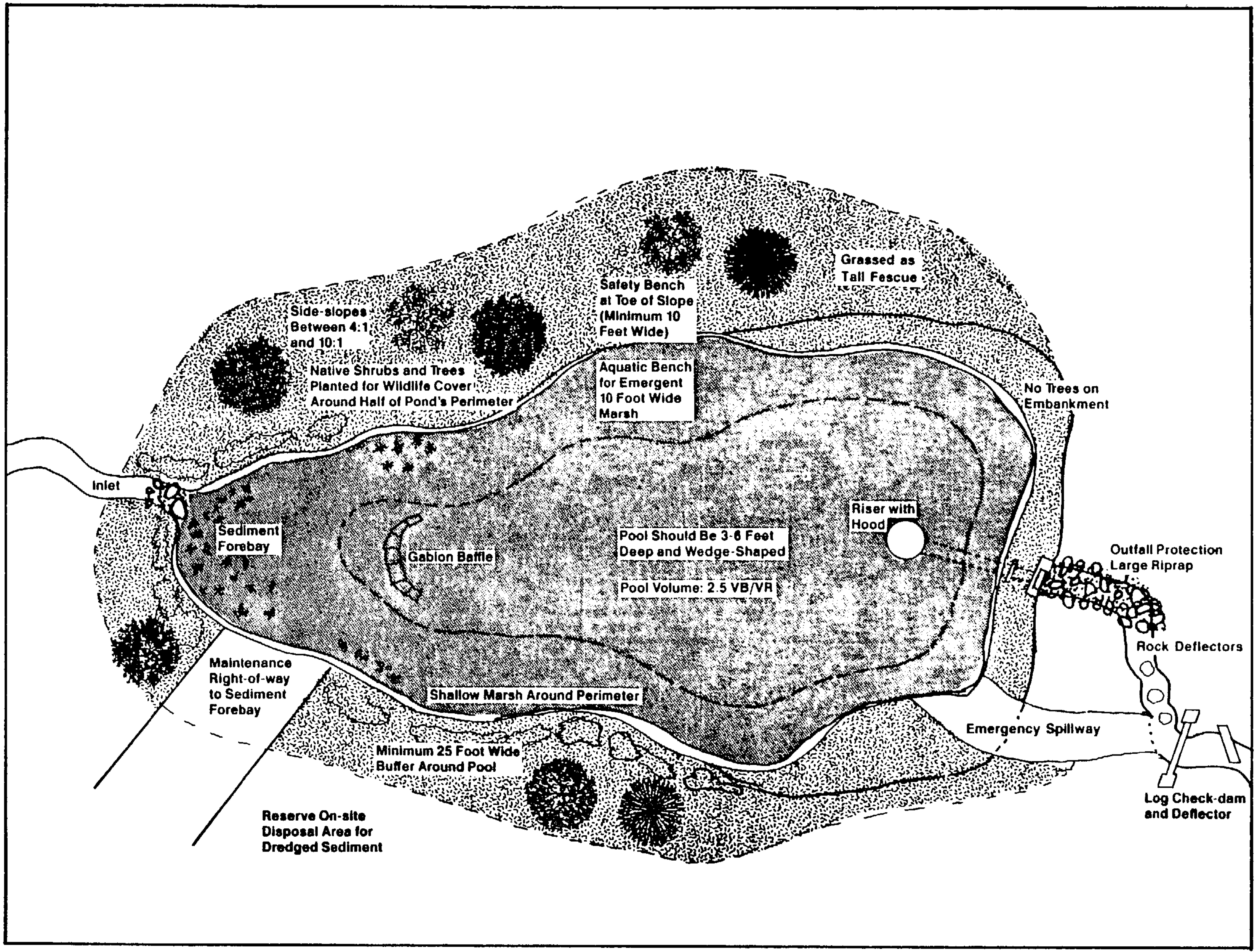


Figure 47. Design Scheme of a Wet Pond (Schueler, 1987)

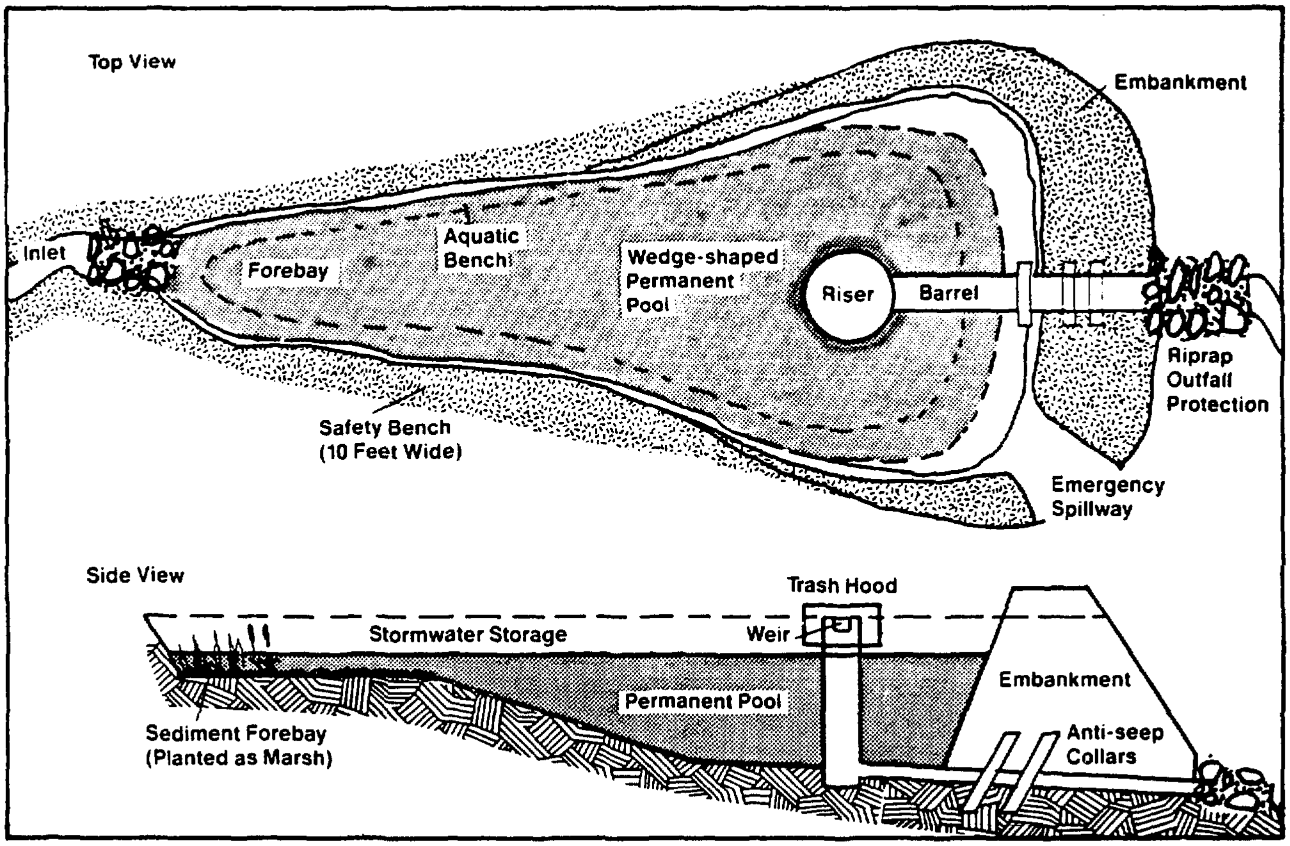


Figure 48. Variations on Wet Pond Design with Extended Detention (Schueler, 1987)

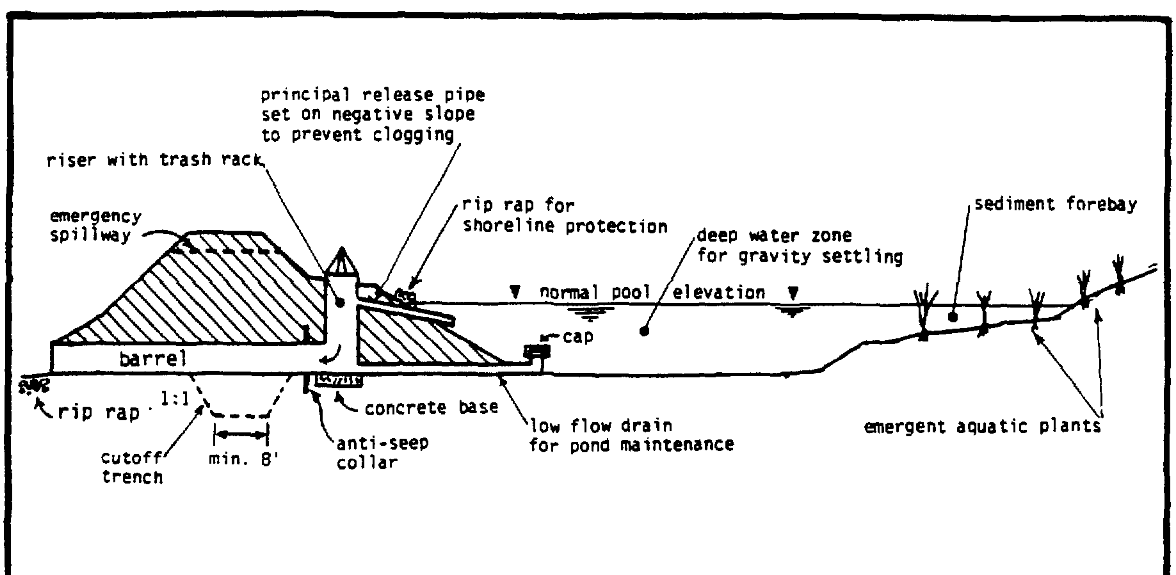


Figure 49. Wet Pond Configurations to Promote Settling (Athanas, 1986)

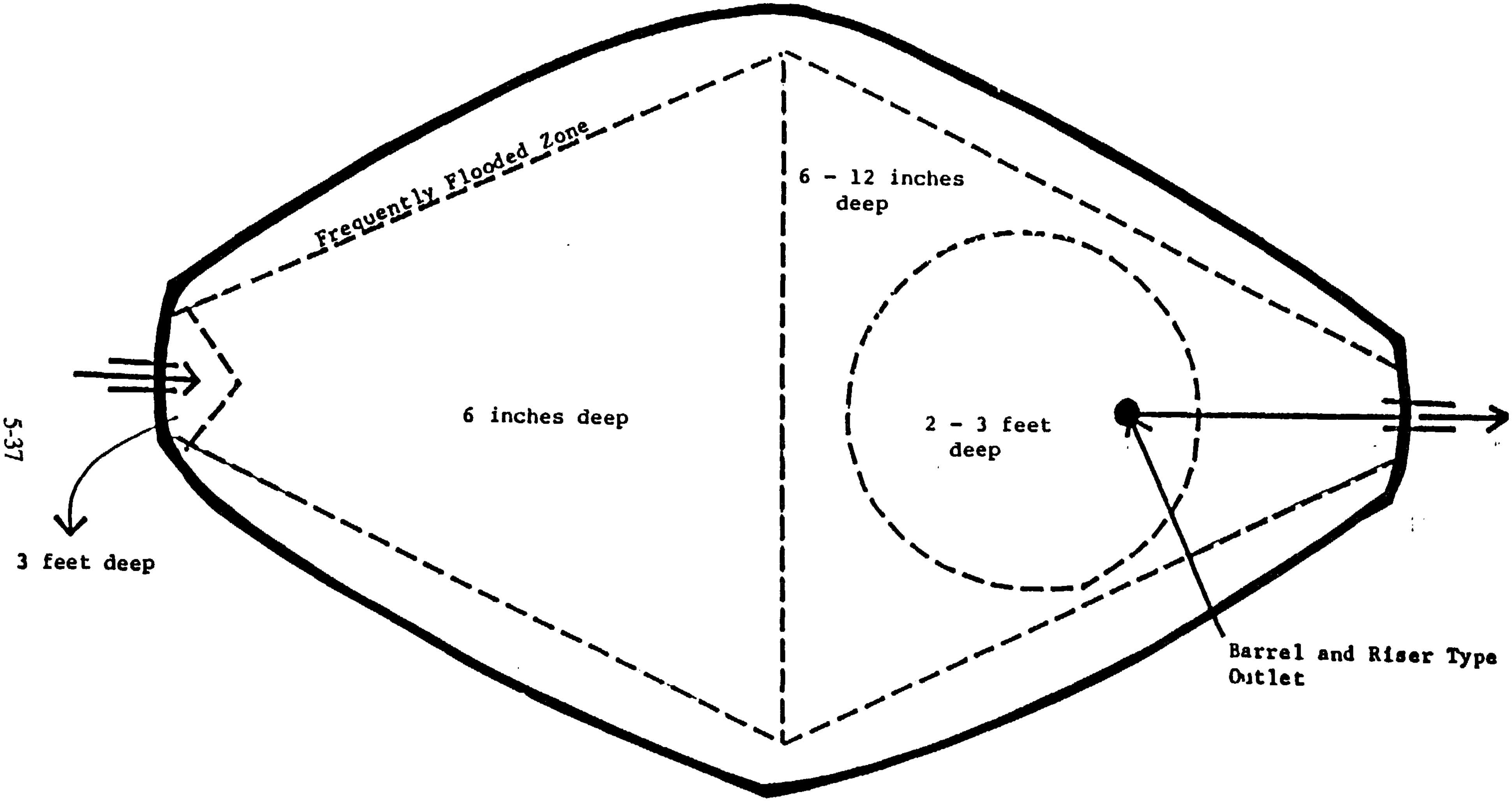


Figure 50. Illustrative Design of a Created Wetland (Athanas, 1986)

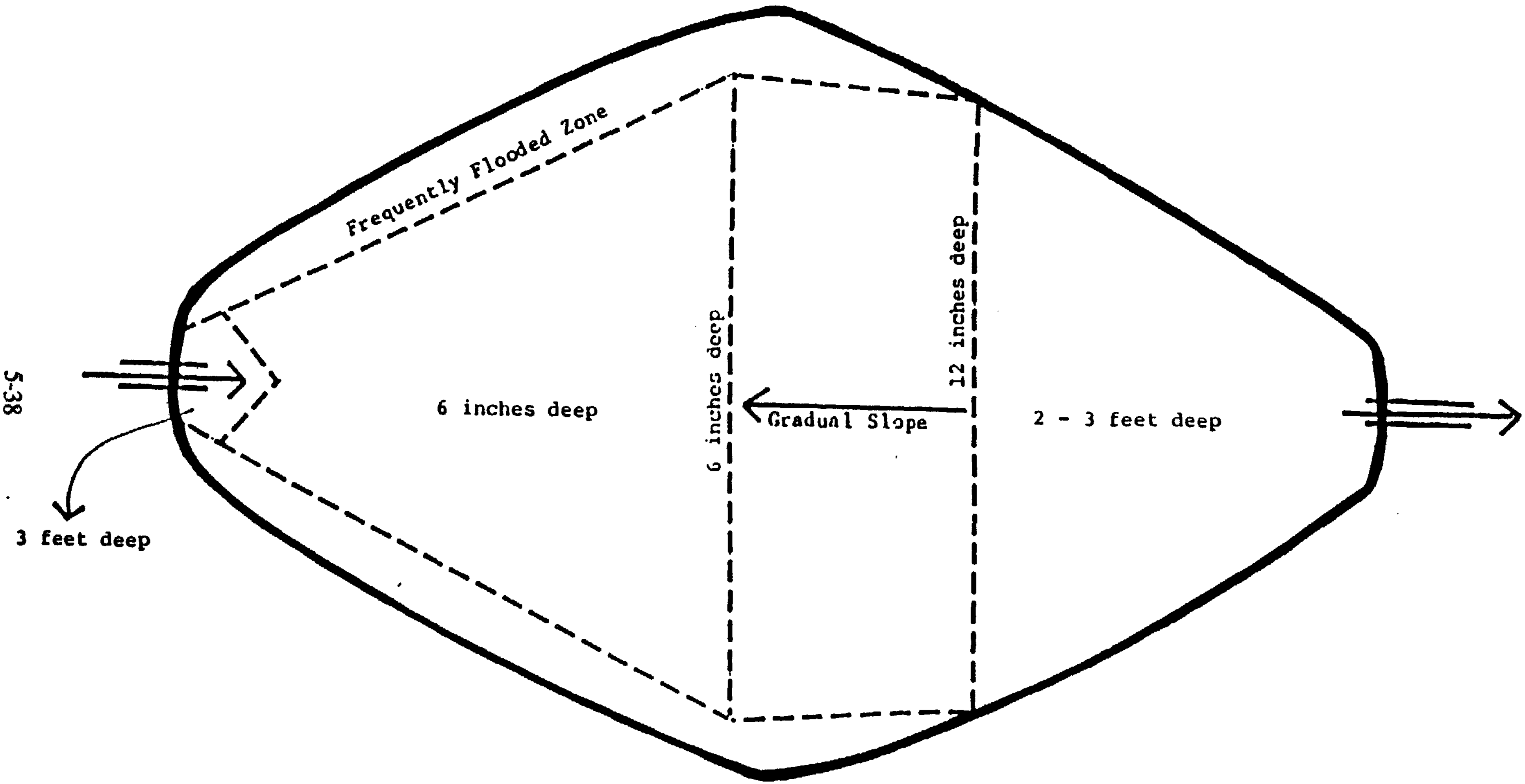


Figure 51. Illustrative Design of a Created Wetland (Athanas, 1986)

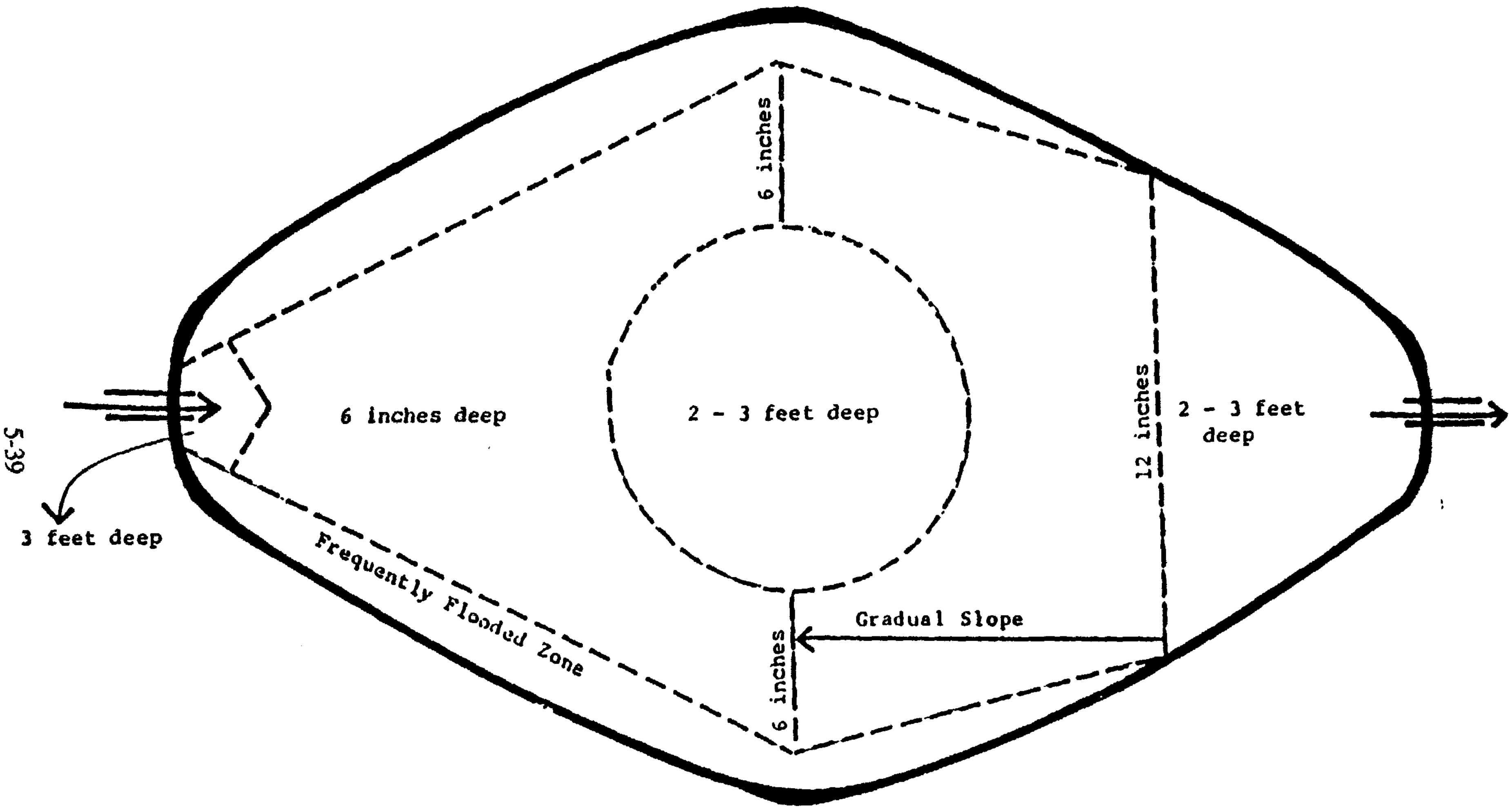


Figure 52. Illustrative Design of a Created Wetland (Athanas, 1986)

"A great deal of sediment deposition will occur near the inflow pipe as the incoming runoff loses velocity upon entering the basin. A limited area around the inflow point should be made sufficiently deep to accommodate this sediment deposition and thus reduce the frequency of required maintenance. It is recommended that an area of approximately 20 square meters directly in front of the inflow point have a depth of at least 90 centimeters."

"After leaving the sediment deposition area, the incoming runoff should pass through shallow areas of emergent vegetation in order to maximize sedimentation and the mixing of runoff with shallow pond water. As much vegetation as possible, and as much distance as possible should separate the basin inlet from the outlet. This is to avoid the so-called "short-circuiting" effect whereby stormwater runoff can flow out of the wetland with only minimal treatment by the wetland. Although using extended detention will certainly minimize short-circuiting, stormwater runoff in excess of the extended detention capacity will be susceptible to short-circuiting."

"Of the 75% of the wetland that should be 30 cm deep or less, it is recommended that approximately 25% range from 30 cm deep to 15 cm deep, and that the remaining 50% be 15 cm or less in depth. An arrangement that should work well would be to have the water depth slope gradually but regularly from the 30 cm depth at the edge of the deep area to the 15 cm depth, and then fix the basin depth at approximately 15 cm throughout most of the remaining 50% of the shallows. The water should gradually get shallower about 3 m from the edge of the pond."

"It is not altogether necessary to have precise depths and a smoothly graded substrate. When grading, however, it would be preferable to err on the side of shallow water rather than deeper water. In addition, the irregularity of the substrate that may result from machinery tracks or other incidental factors will add some diversity to the wetland by promoting the establishment of species with various depth requirements. However, the basin should be graded as carefully as possible to the depth specifications set out above."

Runoff from a 1-year storm should be detained at least 24 hours. Also, at least two aggressive wetland species should be planted as primary species, and three additional secondary species should be planted. The most important maintenance aspect of the artificial wetland BMP will be the requirement that vegetation be harvested periodically and removed from the wetland area. In only this way are the nutrients taken up and removed from the aquatic system. Lacking this harvesting, we must expect maturation of the wetland species over time, their dying off, subsequent decay and decomposition, and then the eventual release of organic material that will continue to enrich coastal waters, unless removed from the system. Although such harvesting techniques are not commonplace at the present time, harvesting is feasible with equipment currently on the market (Figure 53). If this requirement were to become standardized practice, we would expect companies to provide this harvesting service at rates far lower than costs required if each owner were to undertake harvesting individually.

The removal of macrophytes from wetlands and their subsequent drying and recycling (possibly as a fodder for livestock) raises a number of related and interesting issues which should be considered, but are too involved to detail in the context of this manual. Suffice it to say that the decision to design such a coastal drainage nonpoint source BMP will provide the State with an excellent opportunity to monitor and learn from the process, with better applications to follow.

While the removal of biomass as large plant material poses a variety of operational problems, the removal of floating plants, or planktonic algae, is an even more difficult issue. During summer growth periods, the density of algae in wetland basins could be extremely great and will pass directly out of the wetlands and into the coastal waters without removal. The physical removal of algae from natural water bodies has always been a problem and few, if any, efficient methods have

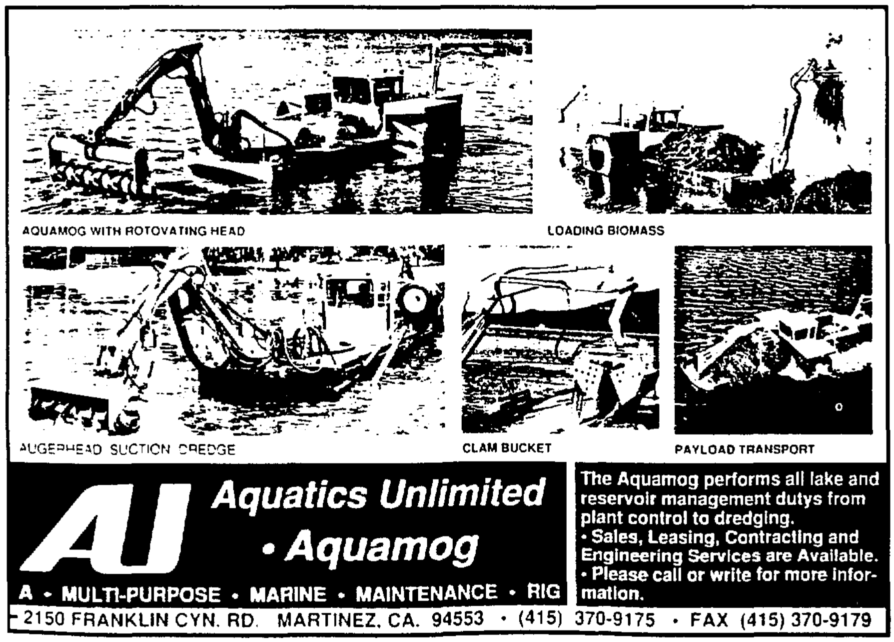


Figure 53. Aquatic Vegetation Harvesting Machines

been applied to existing lake systems to accomplish this removal. One technique which has been brought to NJDEP's attention, though on a somewhat experimental basis, has been put forward by Karl Dunkers, a Swedish engineer. Dunkers has developed several algae removal techniques, one of which is a centrifugal algae removal process which operates in the water body itself and should be fairly inexpensive to operate, perhaps only on a seasonal basis (May through October). This special algae removal technique could be incorporated into the artificial wetland BMP without excessive difficulty. The artificial wetland would be so designed to include this apparatus at its outlet end, thereby accomplishing a remarkably high degree of nutrient and algae removal (Figures 54 and 55).

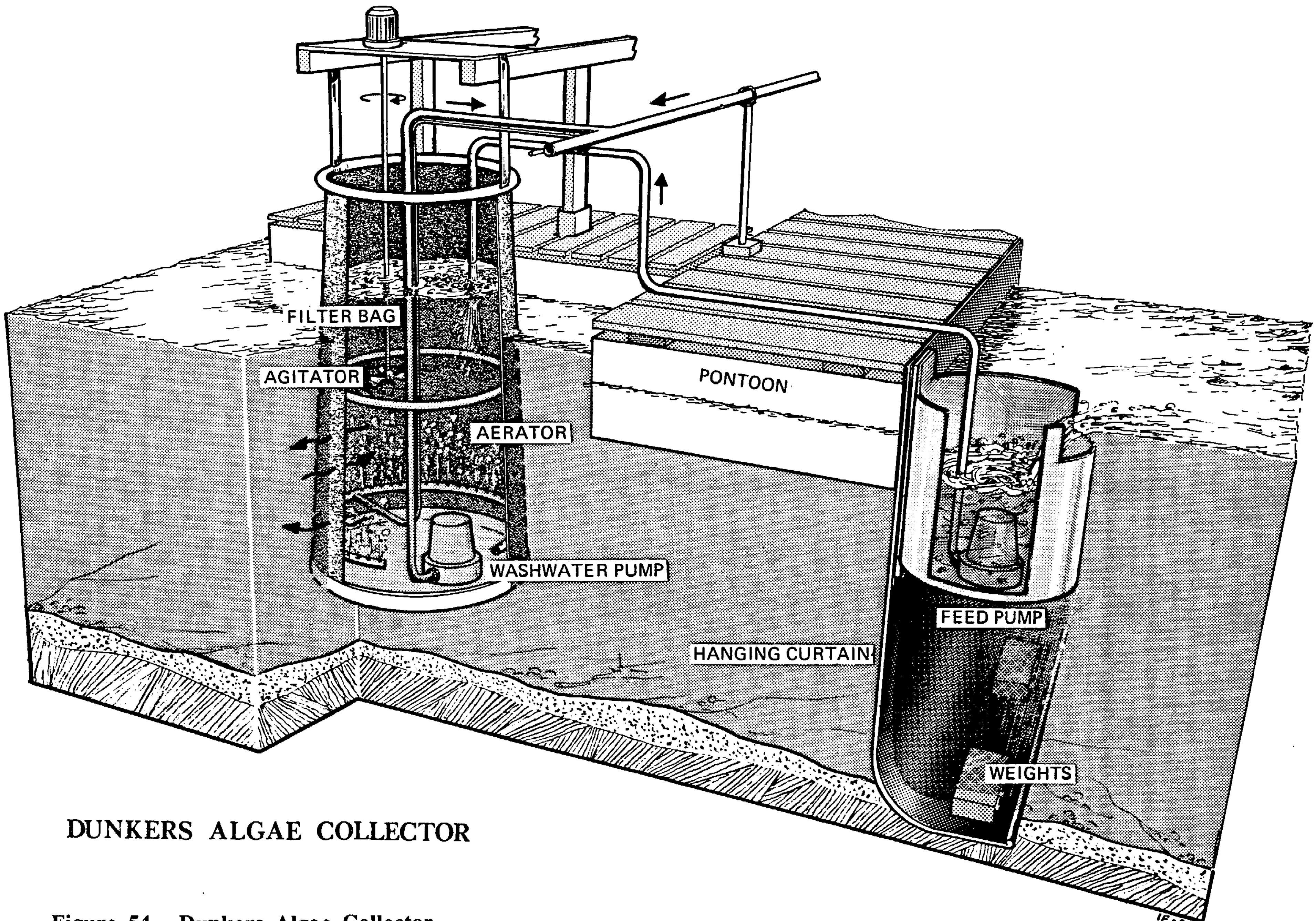
Ideally, the artificial wetland, a wetland harvesting program, and expanded algae removal would be used throughout coastal drainage. However, we are aware that such a requirement could translate into a very expensive mitigation program for a small development and, therefore, may have to be reserved for especially large, especially sensitive, and especially pollutant-intensive proposals. NJDEP may want to further investigate the appropriateness of this and other technology in upcoming research, to be followed by more carefully established guidelines on when such technologies must be used. We would reiterate that the entire problem of nutrient removal, or virtually the entire problem, can be avoided in the first place if a minimum disturbance/minimum maintenance approach to land development is selected.

Efficiency and Effectiveness

Artificial wetlands and wet ponds, if properly designed and engineered, offer the potential for capturing substantial proportions of nonpoint source pollutants through a variety of mechanisms. Although we have assigned these BMP's to pervious area runoff with their primary function being the uptake of solubilized nutrients, the techniques also promote other types of pollutant removal. For example, settling out of particulate material will occur. Athanas reports on a variety of studies undertaken around the country addressing the issue of efficiency of pollutant removal in wetland treatment. In a Minnesota wetland, Hickok et al (1977) reported high levels of phosphorus and total suspended solids removal at the Wayzata wetland, though the output load of ammonia-nitrogen was larger than the input loading. Though heavy metals concentration values showed substantial reductions (82 percent for zinc, 94 percent for lead, 79 percent for copper, and 67 percent for cadmium), there was some question as to whether changes in concentrations could be equated to actual changes in load reduction. In the Swift Run wetland in Ann Arbor, Michigan, a NURP site, Scherger and Davis reported large differences between total phosphorus and soluble phosphorus removed by the wetland (Athanas, 1986):

> "Total phosphorus, which includes that fraction susceptible to sedimentation as well as the soluble fraction had an average removal rate of 42% per storm event. Removals ranged from 0% to 62%....Nitrate-nitrogen was removed from the stormwater runoff at a mean rate of 69%....Removal ranged from a low of 10% during the February snow melt to a high of 95% in August. If the low value in February is removed the mean removal rate of nitrate is 81%, making this the most efficiently removed nutrient form at the wetland....Total suspended solids were removed from the runoff at a mean rate of 76% and at a total rate of 64%....Lead (Pb) is also susceptible to sedimentation...and was removed at a mean rate of 66% and a total rate of 50%."

Pollutant removal effectiveness of wet ponds seems to be somewhat less than that of artificial wetlands, all else being equal. Degree of pollutant removal achieved by a wet pond appears to vary with size and design of the permanent pool as well as the characteristics of the pollutants involved. In an Ann Arbor, Michigan wet pond (the Pittsfield-Ann Arbor retention basin), nutrient removal was shown to be poor. Total nitrogen removal (TKN and NO3) was only 6 percent of the total input. In another Michigan wet pond (Travers Creek), Scherger et al (1983) found greater nutrient removal for both soluble (62 percent) and total (41 percent) phosphorus, with 20 percent removal



DUNKERS ALGAE COLLECTOR

Figure 54. Dunkers Algae Collector

DUNKERS ALGAE COLLECTOR

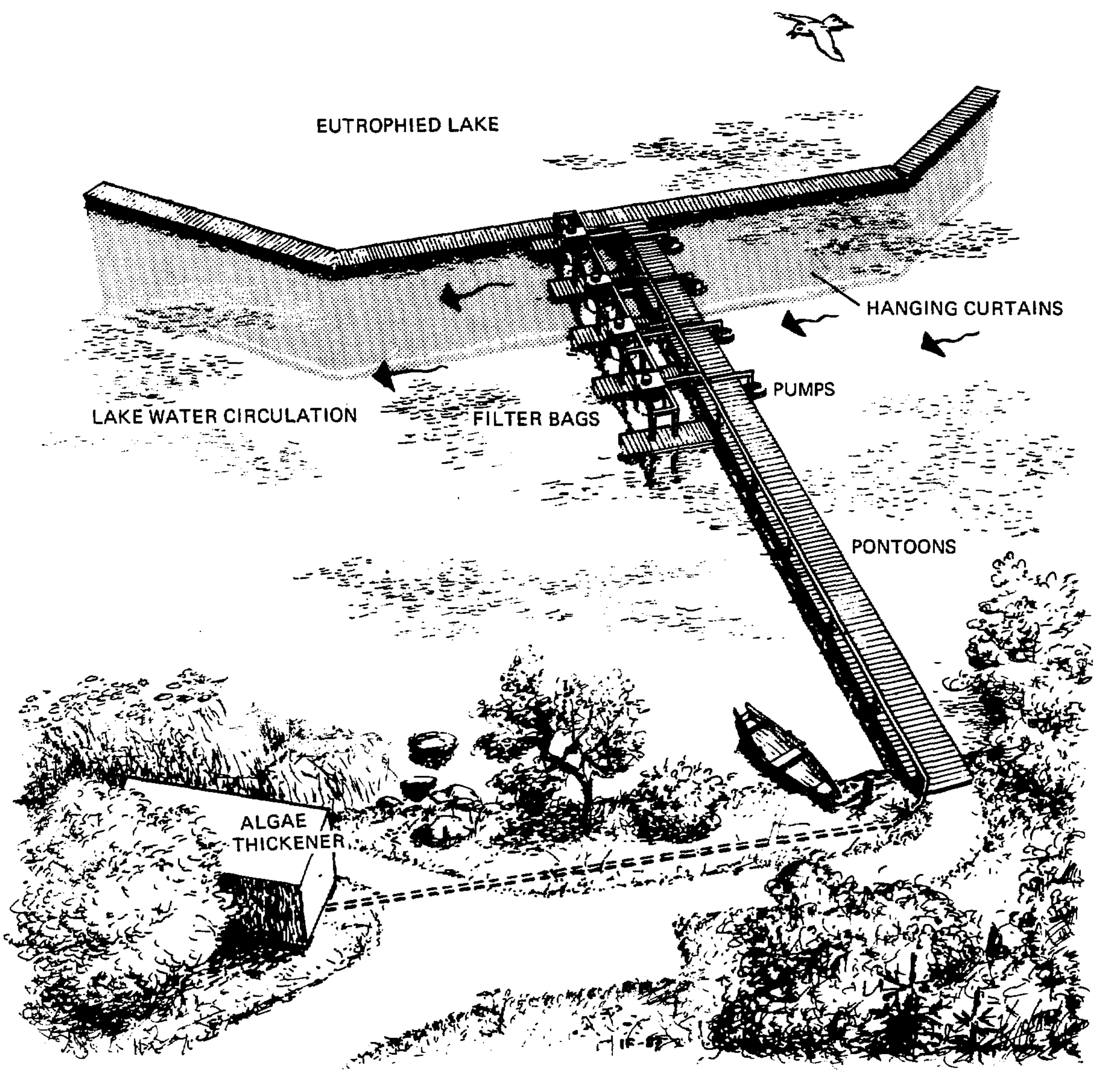


Figure 55. Dunkers Algae Collector Installation in Lake

of soluble TKN, 24 percent for total TKN, 31 percent for nitrate nitrogen, and 28 percent for total nitrogen; also, suspended solids removal was remarkably low (10 percent for total values), as were metals removal rates. At the Waverly Hills, Michigan NURP site, overall removal efficiency of suspended solids was found to be between 80 and 90 percent, with total phosphorus removal at 50 percent, total TKN at only 18 percent, COD at 30 percent, lead at 90 percent, and copper at 36 percent. At Long Island's Unqua pond, NURP study indicated that the wet pond removed 60 percent of the total suspended solids, 45 percent of the total phosphorus, 80 percent of total lead, but had net increases in total TKN and nitrate and nitrite nitrogen. At Lake Ellyn near Chicago, Hey and Schaefer (1983) reported high removal (78 percent or more) of material susceptible to sedimentation (suspended solids, copper, lead, and zinc), high removal (90 percent) of nitrate and nitrite nitrogen, but an actual increase in ammonium. At the NURP site in Fairfax County, Virginia (Burke Pond), researchers found relatively low removal of total suspended solids (37 percent), total phosphorus and total soluble phosphorus removal at 59 and 56 percent, respectively, total TKN and total soluble TKN at 37 and 40 percent respectively, removal of nitrate and nitrite nitrogen at 84 percent, and removal of total nitrogen at 51 percent. At the NURP study site in Rockville Maryland, Grizzard et al (1982) found all nutrient removal percentages greater than 45 percent (total TKN at 46 percent, nitrate and nitrite nitrogen at 71 percent, total nitrogen at 53 percent, total phosphorus at 70 percent, total soluble phosphorus at 51 percent, and total suspended solids at 87 percent). Schueler (1987) also reports somewhat variable levels of pollutant removal for wet ponds:

> "The pollutant removal capability of two wet pond facilities were evaluated during the Washington, D.C. area NURP study....The wet ponds were found to be effective in removing particulate pollutants, with long-term average removal for the two ponds of 54% for sediment, 30% for chemical oxygen demand, 51% for zinc, 65% for lead, and approximately 20% for both organic nitrogen and phosphorus. In general, the removal of particulate pollutants in the wet ponds was very similar to that observed in extended detention ponds. Removal of organic materials was slightly lower in wet ponds in comparison to extended detention ponds, perhaps as the result of export of biomass and/or detritus from the ponds. The wet ponds were more effective in removing soluble nutrients with long-term removal of 60% of the nitrate and over 80% of the soluble phosphorus recorded during the course of the study. Uptake by algae and aquatic plants was apparently responsible for the removal."

> "Wet ponds monitored at other NURP projects...followed the same pattern of pollutant removal observed in the Washington, D.C. area, with high sediment and trace metal removal, moderate removal of organic nutrients and COD, and apparently high removal of soluble nutrients. The absolute level of pollutant removal was found to be primarily a function of the ratio of pond volume to watershed size....Relatively undersized wet ponds had low occasionally negative removal efficiencies, while moderate to large-sized ponds had correspondingly high removal rates."

Wet ponds' removal efficiencies can be enhanced significantly by the introduction of various fish species and other aquatic life known specifically for their high consumption characteristics (this technique, for example, is being used effectively in the over-enriched lagoons adjacent to the golf course at the Bald Head Island development; see Appendix B). The challenge here is to develop a species list for the New Jersey coastal context which can winter over and not have to be re-populated each Spring.

A distinct advantage to wet pond construction, if designed properly, is the ability to vary water levels so as to periodically inundate mosquito larvae. This expressed concern by the New Jersey State Mosquito Commission and others is a real one and will have to be given serious thought by the Division in order to prevent creation of serious mosquito breeding problems. To the extent that permanent pool aquatic life can be maintained, mosquito larvae also will tend to be consumed.

Although artificial wetlands on the face of it sound more ominous from a mosquito perspective, there is no reason why, as with the wet pond, the deep and shallow areas of the artificial wetland cannot be made to perform in the same way as the wet pond, periodically inundating larvae.

A major benefit of both artificial wetlands and wet ponds is the habitat value provided by the technique. These benefits are significant and may compensate for other development impacts which cannot be adequately mitigated. There has been considerable discussion within NJDEP regarding whether or not existing wetlands should be used as part of a stormwater treatment or other water quality strategy. Our recommendations here do not directly confront this issue. By advocating creation of additional wetland in this vital coastal drainage, we do believe that critical wetlands functions which, for so long have been undermined, will be reinforced. Whatever additional artificial wetlands ultimately are created will enhance the State's overall wetlands program.

Specific Directions

We specifically recommend that artificial wetlands and wet ponds be used in those situations where our preferred minimum disturbance/minimum maintenance landscaping approach is not used and where soil renovating potential is not adequate (regardless of land use, where the depth to the water table is less than 12 inches or where water table depth is 12 to 48 inches, but where the cation exchange capacity of the mantle is less than 10) and where infiltration techniques cannot be reasonably employed. We recommend that artificial marshes be used in preference to wet ponds or permanent pool retention basins, as the wetlands appear to be able to remove a greater proportion of pollutants--especially the damaging nutrients which are of such concern in coastal waters.

We would also recommend that developers be allowed to gain credit for using both of these BMP's in situations not otherwise required. For example, in those situations where we would otherwise require at least a dual purpose detention basin (i.e., where soil limitations are similar to those discussed above, but where runoff is coming from impervious surfaces), use of an artificial wetland would be preferable, as additional pollutant removal would occur in the wetland in contrast to the dual purpose detention basin (some nutrient uptake, uptake of metals, etc.). Similarly, a wet pond, though not as effective as the wetland, would also be preferable and should be encouraged. We have not specifically required that these practices be employed in these contexts because the marginal cost of using artificial wetlands and wet ponds versus dual purpose detention basins is considerable, in contrast to the modest pollutant removal efficiency gained.

Recommendations would not vary from the tidal to nontidal situation, although in all nontidal cases, a peak rate criterion would be imposed and could add to the size of the artificial wetland or wet pond.

Multiple Chamber Catch Basins

These measures are not presented at the end of our discussion by accident. They are measures of last resort because of their limited effectiveness and should only be used when other techniques have been rejected for sound reason (lack of space, for example). The most appropriate application of catch basins is in small sites of, for example, less than one acre where proposed site coverage for a new gas station or convenience store is quite high and expected pollution loadings would also be quite high. In such situations, other BMP's may not be workable, and the catch basin, even with its considerable drawbacks, becomes the second best approach.

Catch basins can have a variety of names and take a variety of forms. Schueler labels these techniques water quality inlets. Prior site designs permitted by DCR have made reasonably frequent use of triple chamber catch basins of varying size and shape (Figure 56). Schueler discusses a typical Montgomery County, Maryland triple-chamber design, which consists of a long rectangular concrete chamber (Figure 57), connected to the storm drain system. The box has three sub-chambers designed to remove sediment, grit, and oil. The first chamber, with a permanent pool of water, promotes gravity settling of particulates and floating debris. The second chamber, also with a permanent pool, is designed to trap oil and grease until adsorbed onto sediment particles and settling out occurs. The third chamber is designed for back-up settling as well. Each catch basin must have a manhole so that the periodic clean-out and other maintenance needed can be accommodated.

The actual physical configuration of the catch basin may vary. In any case, there are several design features which appear to promote pollutant removal. First, volume of the permanent pool should be made as large as possible (Schueler recommends at least 400 cubic feet per acre of impervious surface). Vertical baffle plates on chamber floors can minimize resuspension as can use of an inverted pipe with a 90 degree elbow, the vertical portion of which should extend to one foot from the bottom of the inlet. Cleanout should occur at least twice per year.

Another variation on this theme is the incorporation of infiltration in the bottom of the catch basin (Figure 57). However, because of our restriction of these devices to areas with poorly performing soils, such infiltration is not to be recommended in the New Jersey coastal drainage program, as we have established it.

Effectiveness and Efficiency

There are several problems in the basic design of these multi-chamber catch basins which limit their pollutant removal effectiveness. Even if properly designed, the permanent pool is only a fraction of the size of the pool recommended for other first flush BMP's. Because of the reduced size and capacities of the basins, runoff ultimately passes through very quickly. Whereas in other first flush BMP's, a 36-hour non-residential/18-hour residential minimum retention time is imposed, runoff in multi-chamber catch basins may pass through the basin in several minutes. Furthermore, even if pollutants are removed from the runoff, there is the problem of resuspension. Sediment deposited especially during the smaller storms may be resuspended during the larger storms, even if a reasonable maintenance program is followed. In order to avoid this problem, basins would have to be cleaned out after virtually every storm which would be excessively expensive. As stated in Schueler (1987):

> "Sediment tracer studies in catch basins (Pitt, 1985) indicate that only coarse-grained particles (such as grit, sand, some silt and debris) are likely to remain deposited for long periods. Pitt estimated that catch basins could remove about 10-25% of sediment and trace metals, and

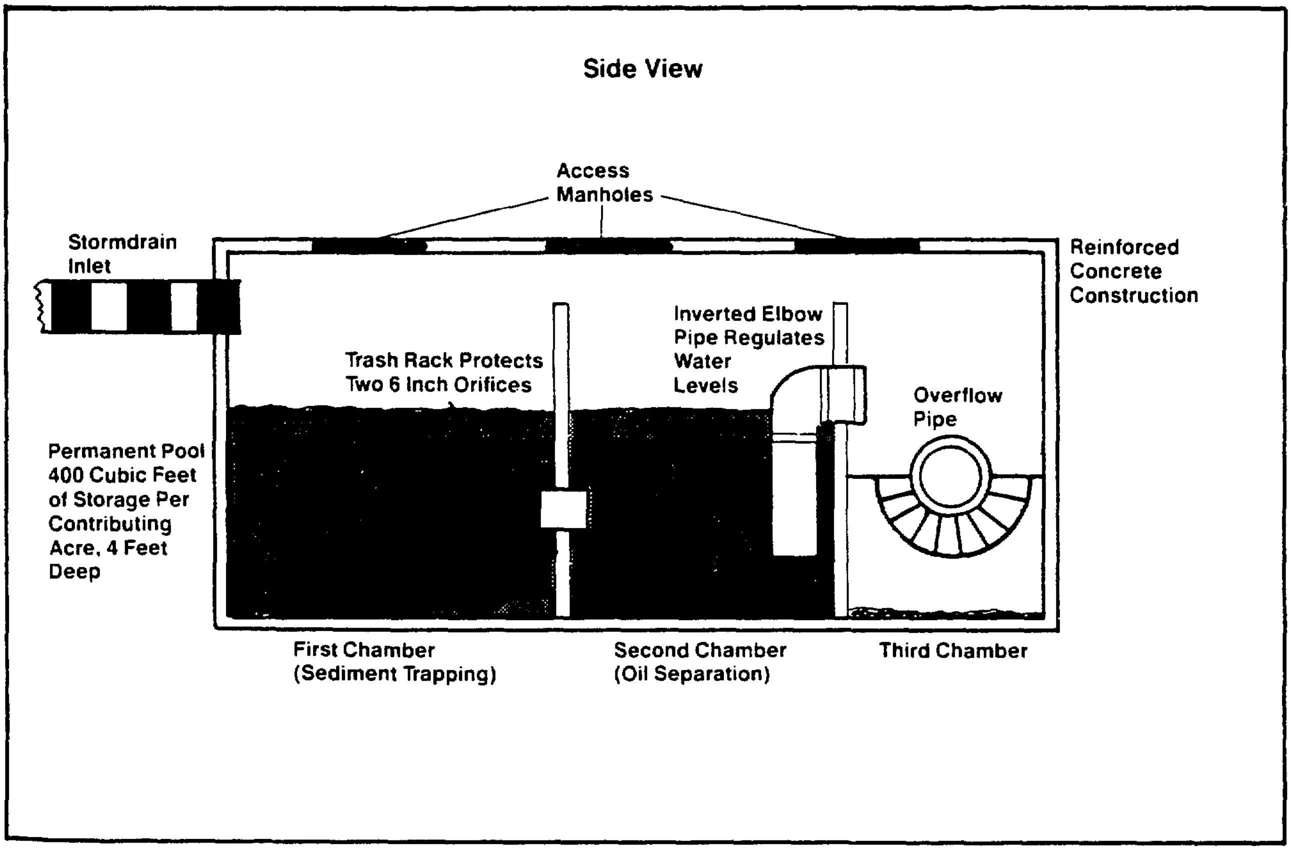


Figure 56. Multiple Chamber Catch Basin (Schueler, 1987)

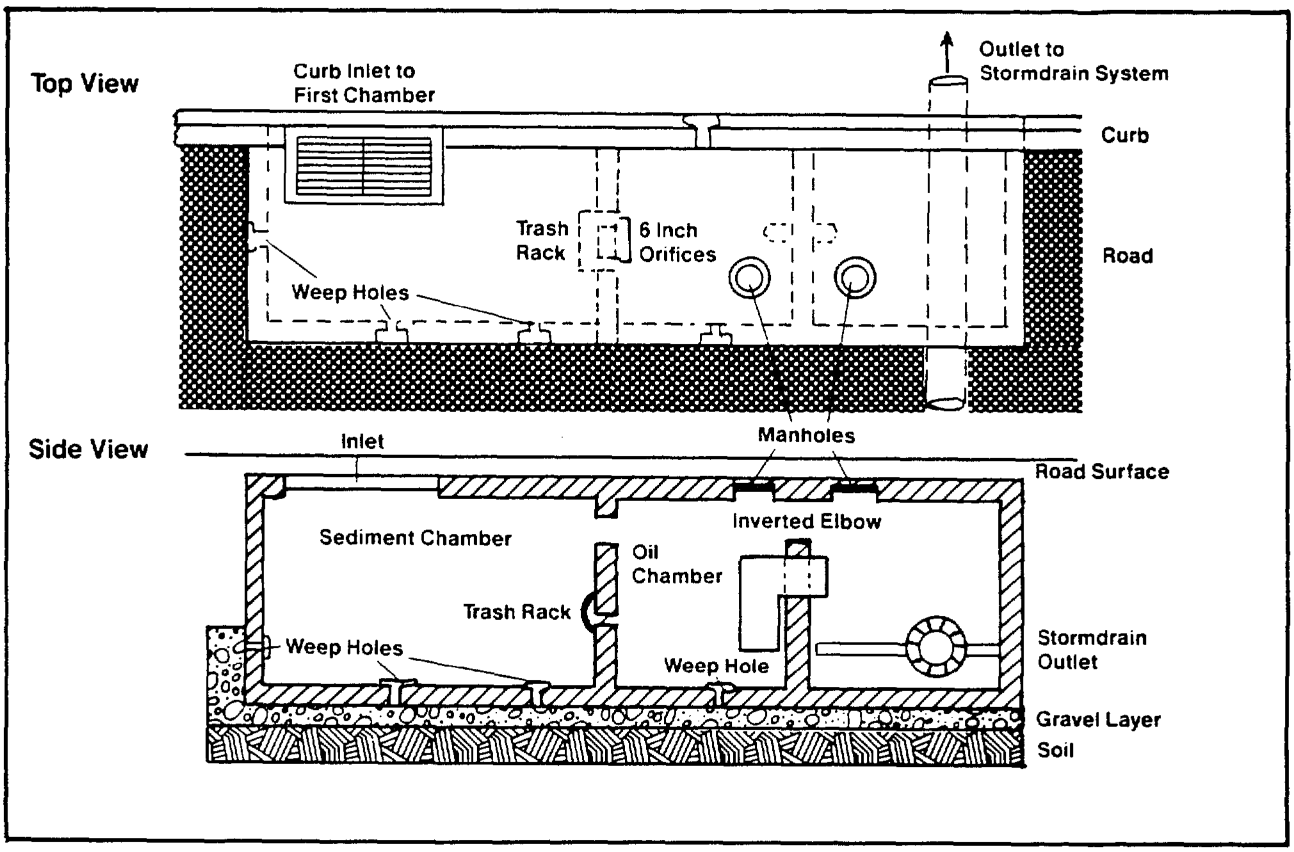


Figure 57. Diagram of a Triple Chamber Catch Basin/Water Quality Inlet (Schueler, 1987)

less than 10% of the nutrients in urban runoff if regularly cleaned. Field observations of accumulated sediments in three-chambered inlets (Galli, personal communication) suggest that inlets may also trap silt-sized particles, but it is not known whether they are prone to resuspension."

"Despite these design limitations, there is reason to believe that inlets can help to remove coarse-grained sediments from urban runoff. For example, settling column studies (Grizzard et al., 1986) indicate that initial settlement of urban sediment is quite rapid, with about 20-40% dropping out within the first hour, depending upon the initial sediment concentration...."

"Also, the design of water quality inlets should provide moderate removal of hydrocarbons. Since oil and gas are less dense than water, they initially float on the water surface. However, since oil and gas have a strong affinity for sediment, they rapidly adsorb to particles in the water column, and can then settle out."

Specific Directions

Catch basins are recommended here for impervious runoff, only as a secondary measure if water quality detention basins or some other more effective BMP cannot be employed. They further should be restricted to only those situations where the natural renovating capacity of the soil is inadequate (i.e., 1. a SHWT less than 12 inches; or 2. SHWT between 12 and 48 inches and with soil cation exchange capacity of less than 10; or 3. SHWT between 12 and 48 inches and with nonresidential land uses, even with cation exchange greater than 10). In tidal contexts, sizing is determined by maximizing first flush retention capabilities.

In nontidal situations, catch basins should not be used in any context. To some extent, this recommendation/prohibition reflects supposition that land availability will be greater in nontidal situations and therefore less effective BMPs should not be allowed. We can accept the reality of having to live with the lackluster performance of catch basins in tight spots along the Hudson River in Jersey City, for example, although in each case the applicant must be made to demonstrate that water quality (or dual purpose) detention basins are not feasible. In nontidal situations, there could be numerous instances in which small parcels with development proposals complying with both local and Coastal Division "Brown Book" impervious cover criteria could nevertheless be shown as unworkable from a dual purpose detention basin perspective. Rather than relaxing criteria and standards in what could be a very large number of cases, we would strongly recommend that the application be denied.

Other BMP's: Combined Sewer Outfalls (CSO's)

One other BMP is appropriate for consideration and discussion in this Manual, even though its application is limited to that portion of the New Jersey coastal drainage which occurs above Sandy Hook, in the urbanized region from the Raritan Bay north along the Authur Kill, Newark Bay, and the Hackensack and Hudson Rivers (outside of the Atlantic coastal drainage area defined in this Manual). The issue here is the discharge from combined sewer outfalls (CSO's), which technically speaking is a point source sanitary sewage discharge diluted with stormwater containing the NPS pollutants from urban drainage. The older communities which were developed along the waterfronts of these estuaries utilized sewerage systems which were "dual purpose" (i.e., conveyed domestic and industrial wastewaters to treatment facilities, as well as storm runoff during rainfall events). In these systems, storm flows are discharged to coastal waters together with untreated sewage during high flow conditions. This discharge of mixed sewage and stormwater occurs via dozens of discharge points which are called "regulators," which are intended to allow only excess storm flows to bypass the sewer system and discharge into receiving water bodies so as not to hydraulically overload sewage treatment plants. In reality, the operation of these regulators has seldom been effective in containing and limiting these discharges (the regulators often become stuck in an open position after the rainfall event, thereby allowing untreated sewage to continue to escape treatment). The net result is either an intermittent or, in some cases, a continuous discharge of raw sewage via storm sewers to receiving coastal waters. The magnitude of this problem cannot be overstated. The 161 sq km area served by combined sewers in Monmouth, Middlesex, Passaic, Essex, Union, Hudson, and Bergen Counties (Mueller, 1982, Table VIII-3) produces an average discharge of 3 m3/sec (68.5 MGD), assuming that 15 percent of the combined runoff is captured by treatment plants (Hydroscience, 1978).

These multiple discharges have been an almost unsolvable problem in coastal waters, because the economics of reconstructing the urban sewer systems in older cities would represent a capital program well beyond the resources of most of these communities. On the environmental priority list at the Federal level, the issue of CSO's has been studied, but not given high priority. Various recommendations for incorporating some amount of storage within the sewage system or modification of treatment facilities generally have gone unfunded by municipalities and unsupported by Federal and State grants. Because CSO's are part of the urban stormwater drainage system, they have traditionally fallen between the cracks in terms of point source discharge regulation. However, with the adoption of new NPDES requirements for monitoring storm sewer discharges by larger municipalities (see Chapter 2), many of these CSO's should receive some measure of regulation in the next few years.

Monitoring the discharge, however, will not eliminate or reduce the pollutant loadings to coastal waters. Unfortunately, technical solutions to the CSO problem seem quite limited. One concept which is presently undergoing testing at a demonstration site on Jamaca Bay, New York, is a discharge containment system proposed by Dunkers (Dunkers, 1978), which consists of a series of floating pontoons and flexible curtains or baffles, set in the receiving water body (Figure 58). The system acts like a set of flexible surge tanks or floating chambers, containing the discharge from the CSO's at the regulator gates or outfall point until the peak of flow in the combined sewer passes. When the flow in the sewage system is reduced and can accommodate additional flow, the stored CSO discharge is pumped back into the system for conveyance to and treatment by the STP. Although conceptually simple in nature and flexible in capacity, this system is subject to a variety of operational constraints, not the least of which is the return pumping operation and the associated

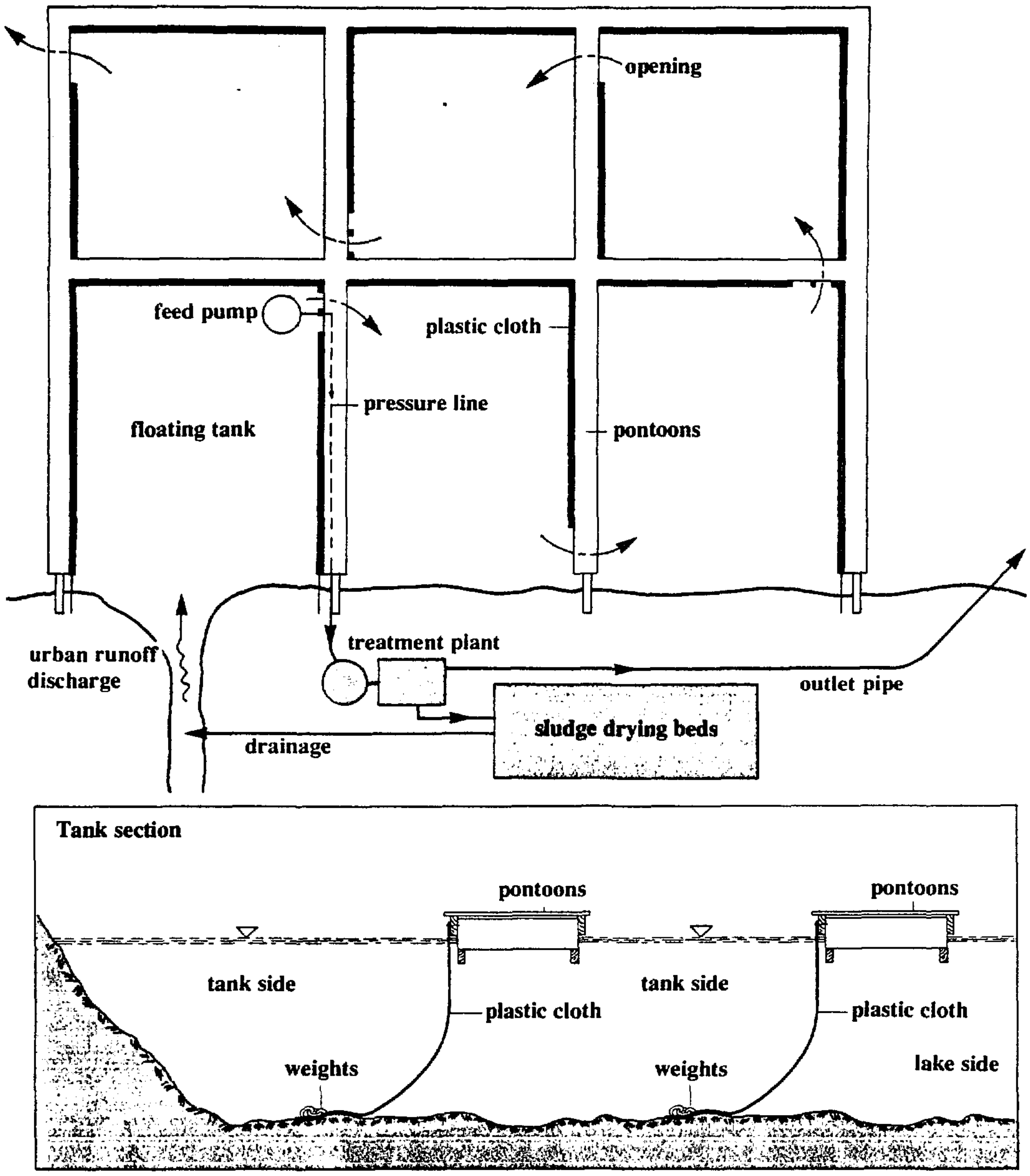


Figure 58. CSO Containment System Design. (Dunkers, 1978) (Jamaca Bay pilot installation collects CSO discharge and returns it to combined sewer based on level control)

costs and difficulties of installation of this system in the various river and estuary locations in need along the New Jersey coast. Because containment chambers serve as temporary settling tanks, settleable solids accumulate on the river or bay bottom, with related decomposition occurring. Although the technique must undergo substantial refinement, this CSO containment system represents a step forward in reducing and hopefully eliminating the discharge of pollutants by CSO's into coastal waters. This system also should be substantially less expensive than any of the more elaborate storage systems involving fixed structures and tanks. The Dunkers system, furthermore, does not involve any substantial treatment processes. As the impacts of NPS pollutant discharges to this portion of the New Jersey coastal environment are better evaluated, containment of CSO discharges will be an important part of the planning for improved water resource management.

Data Collection and Sampling Programs

Throughout this Manual there has been reference to insufficiency of data in order to understand fully the water quality problems occurring and expected to occur in Atlantic coastal drainage. In terms of applications of various best management practices, the literature is also deficient in terms of the water quality performance of various BMP's, especially in situations similar to those in New Jersey. Consequently, am excellent best management practice would be to require that permit applicants conduct both "before and after" water quality monitoring in order to remedy some of these data gaps.

NJDEP's Division of Coastal Resources has already been issuing coastal permits with these monitoring stipulations included. Probably most notable is the very large Smithville development, where the developers have conducted and continue to conduct periodic water quality sampling for surface and groundwater. In most cases this sampling is designed to first assess the ambient or baseline water quality prior to development. Sampling is then conducted during and after development, in order to assess effectiveness of the stormwater management plan and the various BMP's put in place. We have reviewed similar sampling programs which NJDEP has required for permit issuance at the large Port Liberte development along the Hudson River in Hudson County, the Mattix Forge development, and others . If carefully conceived, coordinated, and designed, these monitoring plans offer the potential of resolving some of the gaps in our baseline knowledge of water quality in coastal waters, although rigid quality control must be maintained throughout the handling of the sampling program. In order to accomplish this objective, the Division should assign oversight responsibility to an experienced staff person, whose duty it will be to manage data collection efforts (possibly this function can be performed jointly with Division of Water Resources staff). Hopefully, post-development monitoring will also enable the Division to gain more understanding of the most effective BMP's to be used in the Atlantic coastal drainage context. That is not to say that the State and other agencies should not expand their sampling programs themselves, as discussed above. Nevertheless, permit applicants must realize that a reasonable amount of water quality sampling will invariably be a permit requirement.

APPENDIX A.

CASE STUDIES
CURRENT STORMWATER MANAGEMENT PRACTICES
AS REGULATED BY NJDEP'S DIVISION OF COASTAL RESOURCES

CASE STUDIES

CURRENT STORMWATER MANAGEMENT PRACTICES AS REGULATED BY NJDEP'S DIVISION OF COASTAL RESOURCES

In Chapter 2, the existing regulations which control the design and development of stormwater management facilities reviewed under the Division's current guidelines were discussed. It was apparent that a great portion of the new development which has occurred and is planned for the Atlantic coastal drainage is not specifically covered by these guidelines, and so they are applied to only a limited number of new projects. Even with this limited application, a tremendous volume of permit applications are reviewed by DCR staff, with recommendations made regarding stormwater management facilities. These design criteria are based on both the specific concerns discussed in the guidelines and the collective wisdom developed by staff over the past fifteen years of permit review. In this context, much is required which is not documented in specific design guidelines, but which is considered appropriate best management for coastal stormwater facility design. Perhaps the best way to describe current practices, insofar as they are recommended by and through the CAFRA review and permit process, is to review and discuss a series of specific applications or case studies which have been processed, or in some cases are still in the review and permitting process. These case studies are intended to focus on the detailed problems encountered in selecting appropriate design requirements for stormwater facilities in the Atlantic coastal drainage, and to offer specific examples of problems which the DCR staff must deal with in the permit process. They also reflect site design techniques which have come into practice by the design community, and in that sense are examples of improved practices which have evolved over the past ten years. All remarks are preliminary in nature and do not represent final critique by DCR, based on complete file information, nor do they represent the final permit requirements in all cases.

CASE STUDY 1. TOWNHOUSE DEVELOPMENT

American Resort Park: Pleasantville Borough, Atlantic County; 350 townhouses on 26.7 acres; 42% impervious is proposed with 80% allowed; the stormwater system uses stone-filled trenches in rear yards for rooftop runoff plus five detention basins and a porous paved area in the section closest to the intermittent stream. Two-chambered catch basins are included in all inlet designs to filter silt and grease, and porous piping is used as well.

Remarks: This design gets high marks for stormwater system concepts. The nonpoint pollutant loadings should be effectively mitigated by this stormwater plan design which provides adequate recharge through both the trenches and the recharge basins. Because no outlets are provided, we assume here that these basins have been designed to adequately accommodate design storm events and provide recharge and therefore should be considered to be retention/recharge basins, rather than simply detention basins. The porous paving furthers the recharge concept; we wonder why porous is not being used throughout the site, possibly eliminating or reducing space-consuming basins and enabling more units to be constructed.

CASE STUDY 2. INDUSTRIAL WATERFRONT SITE

Autoport: Bayonne and Jersey City, Hudson County; 135 acres of paved parking area for marshaling cars; stormwater system includes shallow recharge/filter beds beneath paved parking areas fed by porous concrete piping.

Remarks: Few details were available regarding this system. Given the fact that this facility will be used primarily only for storage and distribution of new cars, will not hydrocarbon and other pollutant loadings associated with vehicular traffic be minimized in any case? A concern was raised that, due to high water table conditions, the crushed stone-filled recharge filter beds might not function to adequately receive the first flush of stormwater (defined in this design as the 1-year, 24-hour storm event). We would recommend use of porous pavement and eliminating the concrete piping system altogether, or greatly reducing it. Because of the relative lack of vehicular activity here, we would expect that pollutant deposition on the paved surface would be modest, and that the potential for any pollutants to leach through the sandy soil and contaminate groundwater is comparably slight.

CASE STUDY 3. SENIOR CITIZENS HIGH-RISE APARTMENT

Baltic Plaza: Atlantic City, Atlantic County; 31,298 sq ft on 0.7 ac. for 81.3% impervious; 168 elderly residential high-rise units.

Remarks:This file is missing details on the stormwater management system, though porous paving was supposedly used, with overflow into the existing city storm sewer. Completed in 1980, no follow-up monitoring study and analysis was made to evaluate just how well the system has functioned. As an example of a small, high intensity site development in an existing urban setting with infrastructure, this site would make a good case study for future evaluation.

CASE STUDY 4. MAJOR COMMERCIAL RETAIL MALL

Bayshore Mall: Lower Township, Cape May County; 64.7 acres with 1,175 parking spaces and 180,000 sq ft of building area; 50% impervious is proposed with 80% allowed. The stormwater plan includes conveyance of all roof drainage directly into adjacent existing wetlands where species of special importance have been identified. All remaining impervious areas are drained into two large retention basins for recharge into the ground; inlets are outfitted with oil skimming devices.

Remarks: It is of interest to estimate the potential pollutional loading from this complex, since it appers to have applied reasonable methods for stormwater management. NPS pollutant loadings would be as follows (Cahill and Associates, 1988, based on factors from Schueler, 1987 and other sources):

Total nitrogen	573 lbs / yr
BOD	9,500 lbs / yr
Zinc	66 lbs / yr
Lead	98 lbs / yr

The basic concept of the stormwater plan here is sound. We believe that use of the existing wetland areas in the rear of the site for rooftop drainage is sound and should be mutually beneficial, providing water to the wetlands themselves as well as using the wetlands for stormwater treatment purposes. The concept behind the recharging retention basins is sound; however, we would recommend that the retention basin be designed in conjunction with a vegetated wet pond. In so doing, less space and less fill should be required. Furthermore, the vegetation should promote nutrient uptake and the filtering of heavy metals.

CASE STUDY 5. SINGLE-FAMILY RESIDENTIAL

Berkeley Estates: Berkeley Township, Ocean County; 64.8 acre tract with 12% impervious; 102 single-family detached units. According to NJDEP staff, the final stormwater plan will consist of the 3 detention basins as shown in the plan (one major detention basin with outlet/overflow and two minor basins) plus dry wells for roof runoff.

Remarks: based on summary nonpoint pollutant calculations, the development will generate the following annual pollutant loadings:

Total phosphorus	22	lbs / yr
Total nitrogen	171	lbs / yr
COD	3,046	lbs / yr
BOD	436	lbs / yr
Zinc	3	lbs / yr
Lead	1.5	lbs / yr

Once again, we do not take issue with the proposed use at the proposed density--after all, current Coastal Policies would allow up to an 80% maximum impervious cover, in contrast to the proposed 12%. And dry wells, if properly designed, will be useful in recharging roof runoff. However, the bulk of the pollutant loadings, as set out above, will not be affected, flowing both from newly paved areas as well as from lawns and maintained areas which will drain into the storm sewer system. The bulk of this runoff in turn is directed into one detention basin where some modest recharge may occur with comparably modest pollutant reduction. Most of the water will be released into the adjacent stream, only temporarily held and with resultant elevated pollutant loads.

Though the site has a difficult shape, we would first recommend that some sort of clustering be attempted (if not reconfiguration of the units themselves into townhouses or quads or garden apartments). If the fee simple small-lot subdivision is unavoidable, then lawns and maintained areas should be directed into naturally vegetated swales with check dams, possibly connecting with wetland areas, with maximum reliance on existing vegetation and re-vegetation with native species to minimize on-going maintenance and landscaping requirements. Infiltration trenches and basins should be explored, with possible elimination of curbs and gutters and reduction of the elaborate stormwater conveyance system currently proposed. If detention basins must be used here, feasibility of a wet pond should be investigated, rather than use of simple detention devices.

CASE STUDY 6. MAJOR HIGH DENSITY RESIDENTIAL

Four Seasons (Colonies): Lakewood Township, Ocean County; 2,400 dwelling units on 408 acres in 10 phases, including patio homes, small and large duplexes, and highrise units. Approximately 30% impervious; stormwater system consists of a system of detention basins and swales fed by either conventional drainage inlets and concrete storm sewers or recharge inlets with perforated storm drain pipe.

Remarks: based on summary pollutant loading calculations, the proposed development would generate the following nonpoint source pollutant loads:

Total phosphorus	280	lbs / yr
Total nitrogen	2,130	lbs / yr
COD	37,900	lbs / yr
BOD	5,400	lbs / yr
Zinc	39	lbs / yr
Lead	19	lbs / yr

Based on the proposed storm drainage plan, it appears as though the bulk of the storm drain system will be conventionally fitted, and the pollutant impact significant. We would not expect the proposed system to have an appreciable effect in reducing nonpoint loads. The recharge potential with this design is quite limited, given the enormous size of the development and the large expanse of impervious and maintained surfaces. No special infiltration devices such as trenches or basins or porous paving and recharge beds are planned. Such measures and others such as wet ponds should be incorporated into the system of open space to some extent. We surmise that the bulk of the area will be maintained under common ownership and maintenance, thereby creating the potential for controlled applications of fertilizers, herbicides, and pesticides. This should be translated into a deed requirement as soon as possible. Also, landscaping should not only strive to preserve existing tree stands, but should also promote use of native species.

CASE STUDY 7. SINGLE-FAMILY RESIDENTIAL

Georgetown at Barnegat: Barnegat Township, Ocean County; 116 single-family detached units on 27 acres; 26.8% impervious is proposed with 80% allowable. The stormwater system elements include roof drywells in those instances where appropriate (i.e., drainage away from structure) and porous piping to a detention basin with stream discharge.

Remarks: nonpoint source pollutant loadings from the proposed development would be as follows:

Total phosphorus	17	lbs / yr
Total nitrogen	128	lbs / yr
COD	2,270	lbs / yr
BOD	326	lbs / yr
Zinc	2.4	lbs / yr
Lead	1.1	lbs / yr

Nonpoint source management is not adequate for this plan. The bulk of the nonpoint loadings will end up being discharged into the stream. If this development concept must be pursued, then more recharge needs to be designed into the scheme through use of more clustering, more naturally-vegetated swales with check dams, and infiltration trenches and basins.

CASE STUDY 8. WATERFRONT MARINA WITH RESIDENTIAL AND COMMERCIAL

Harbor Town: Lower Township, Cape May County; 196 multi-family dwelling units with a 100-seat restaurant and upgrading of an existing marina on 55.9 acres. The stormwater management utilizes detention basins designed for the 2-, 10- and 100-year storms in combination with use of overland swales.

Remarks: given the direct ocean drainage at this site, design to achieve no exceedance of pre-development peak rate or volume seems irrelevant per se. Quality of stormwater runoff is the only issue here. Site impervious coverage will be high, and the potential for pollutant input is very great. A strategy which includes both wet ponds with pollutant uptake facilitated by wetland vegetation, together with porous paving and underground recharge, should be employed in conjunction with the natural swales. This system would exploit both natural purification of the soil mantle enhanced by plant uptake, with consideration of seasonal harvesting. Minimum maintenance landscape management should be incorporated to prevent fertilizer and chemical usage. Marina activities (fuel and servicing) should be evaluated to prevent spillage and made foolproof. Treatment of bulkhead materials should be reviewed.

CASE STUDY 9. TOWNHOUSES AND GARDEN APARTMENTS

Heather Croft: Egg Harbor Township, Atlantic County; a total of 107.15 acres with 442 dwelling units (138 townhouses and 304 garden apartments) and 46,500 sq ft retail/commercial uses. Impervious ratings are not provided; stormwater system elements, though not fully developed, include a detention basin (Basin A) for 20 residential units and the commercial area, an existing artificial recharge swale system, a swale connecting to an existing wetland area, and additional recharge/filtration between parking stalls.

Remarks: Insufficient information to develop analysis of pollutant loadings, but overall plan is weak. Use of wet ponds/wetlands should be incorporated, and minimum maintenance reflected in site landscape design. High potential for significant pollutant impact.

CASE STUDY 10. HIGH DENSITY CONDOMINIUMS

La Quinta: Lower Township, Cape May County; 102-unit, 6-story residential condominium with 207 parking spaces on 2.7 acres; 83.7% impervious proposed with 90% allowed. The stormwater system includes the use of porous pavement, though with only a 4 inch stone-filled recharge bed, plus seven different drainage fields consisting of porous pipe in filter fabric-wrapped crushed stone-filled drainage beds.

Remarks: Although the information provided is sketchy, the proposed concept is basically sound, with improvements. Recharge bed is insufficient thickness. We would question why the system is not simplified by making the recharge areas beneath porous pavement uniformly deeper, thereby eliminating the drainage field elements. Minimum maintenance should be included in landscape design.

CASE STUDY 11. MEDIUM DENSITY TOWNHOUSES AND SINGLES

Laurel Chase: Dover Township, Ocean County; 230 townhouses and 97 single-family detached and recreational facilities on 85.0 acres; 29% impervious is proposed with 80% allowed. The stormwater system elements include use of dry wells for rooftop drainage, porous pipe in non-traffic areas, 34 ft. street widths reduced to 28 ft., plus five large detention basins.

Although the final stormwater plan was not available, the overall plan is lacking from a quality perspective. In the multi-family sections, what about porous paving and underground recharge beds for parking areas? Infiltration trenches and basins/wet ponds should be used for single-family lot areas (including drives), all integrated into an overall landscaping design of minimum disturbance/minimum maintenance, which retains natural vegetation, maximizes native species, and minimizes maintained areas. If basins are used, wet basins with wetland vegetation should be the basic design.

CASE STUDY 12. ADULT RESIDENTIAL

Lionshead Woods: Lakewood Township, Ocean County; 281 adult residential units on 71.9 acres; applicant proposes 34% impervious in area where 80% is allowed. The stormwater management includes rooftop runoff being directed onto vegetated areas, drives sloped onto lawns, smaller feeder streets built without curbs, and detention basins with rock-filled recharge channels or infiltration trenches included.

Remarks: nonpoint source pollutant loadings would be as follows:

Total phosphorus	54 lbs / yr
Total nitrogen	418 lbs / yr
COD	7,400 lbs / yr
BOD	1,065 lbs / yr
Zinc	8 lbs / yr
Lead	3.8 lbs / yr

We assume here that common ownership and maintenance of the site will be provided. Strict attention--deed restrictions--should be given to eliminate applications of fertilizers, pesticides, and herbicides. As in most cases, we have no particular problem with residential use at this density, although we would prefer greater clustering and possible reconfiguration of units to minimize site disturbance and maximize preservation of existing vegetative cover. If this development concept is to be pursued, we would advocate use of infiltration trenches with native vegetative species to contain drainage of the yards and maintained areas. Additionally, we would advocate that the remaining runoff be handled with recharge inlets, porous piping, and wet basins to promote recharge and minimize any release of stormwater from the site. Common parking areas for the recreation facility--even the tennis courts themselves--should be porous paving on top of underground recharge beds.

CASE STUDY 13. HIGH DENSITY SINGLE-FAMILY

Meadows at Mantoloking: Brick Township, Ocean County; 61.85 acres with 15.4% impervious cover; 246 single-family dwellings and related services; two aerated retention basins for the 100-year storm were rejected due to groundwater interference (i.e., high water table, reducing storage capacity); though development is pending, we understand that if volume is provided, this stormwater management concept will be approved.

Remarks: Based on summary calculations, nonpoint pollutant loadings for this development would be as follows:

Total phosphorus	25 lbs / yr
COD	3,400 lbs / yr
BOD	490 lbs / yr
Zinc	3.6 lbs / yr

Lead 1.7 lbs / yr

This project offers the potential for significant pollutant input to coastal waters. The proposed aeration ponds would serve to reduce COD and BOD loadings, although the solubilized nutrients and metals would not be affected by this system and would basically be washed through and into the Metedeconk River. We would recommend that a variety of alternatives be explored here, with the objective of eliminating pollutants as close to the source as possible, or reducing their potential input:

1. If local land development regulations permit, the first issue here relates to the proposed use and the manner in which the building program is executed. The site is located within a High Development Potential region. We have no particular problem with residential use here or even 250 units of residential use. However, we would first advocate that a different unit type such as townhouse or garden apartment be used. If single-family detached must be developed, then the site plan should strive for substantial clustering with common open space and parking areas to facilitate control of operating/maintenance practices. As it is now, the site plan creates 246 separate yards, all of which must be maintained individually, all of which must be fertilized and sprayed, all of which most probably will be landscaped as distinct units, without regard to drainage.

2. Given the site's proximity to the River and Bay, peak flow and flood impacts should be evaluated seriously. Unless there is some real flooding problem between the development and the River, the concept of no increase in peak rate of discharge is irrelevant here. Thus, the purpose behind the aerated retention basins is undermined. Potential for wet ponds and possibly even wetlands creation should be explored as an overall concept and could be critical, although their attenuation of peak flows would be secondary. Again, quality of stormwater is the major concern.

3. Additionally, rear yard swales could be designed, linked with common natural landscaping bands to retain and filter stormwater. Site drainage would have to be adjusted appropriately. Check dams could be provided in these natural "mini-corridors." These "water quality drainage easements" should be protected by deed restrictions.

4. Ideally the entire development should be deed restricted to prevent improperly applied fertilizer and pesticide/herbicide applications. The design of small, single family parcels will made this extremely difficult.

CASE STUDY 14. HIGH DENSITY WATERFRONT RESIDENTIAL AND MARINA

Port Liberte: Jersey City, Hudson County; 1,690 dwelling units, a 245-slip marina, 540 canal boat slips, a 300-room hotel, and a 46,000-sq ft commercial space with related parking on 156 acres of land and water. The stormwater elements include sub-surface trenches lined with sand, gravel, and filter fabric to receive water from roofs, parking, and road areas. Other runoff is designed to sheet flow overland directly to the canals. Special catch basins/separators also are to be included where appropriate (this doesn't seem to be specified). Water quality monitoring also is required in the canals in order to make sure that the canal system meets water quality standards.

Remarks: The scale of this project and its proximity to the New York harbor waterfront make it an interesting case study. While both the size of development and the quality of the receiving water body are very different from a marina situated along the direct Atlantic drainage region, the approach to stormwater quality management should follow the same guidelines. Roof drainage should be conveyed directly to reduce the hydraulic loading on recharge systems from land surfaces. Minimum maintenance landscaping should be included throughout the tract, and all plantings containerized. Marina activities should be made spillproof, and stringent criteria set for usage and maintenance of vessels. Sheet flow from surface is worst approach to NPS management, and pervious surfaces should be included at edge of tract. Monitoring of canal water will reflect poor condition of harbor, and not evaluate runoff impacts. Storm event sampling of direct runoff should be included, for selected parameters in Tables 19 and 20. Dustfall sampling on rooftops should also be included.

CASE STUDY 15. SINGLE-FAMILY RESIDENTIAL

Stemark (Lanes Mill Estates): Brick Township, Ocean County; 66 single-family detached on 22.7 acres; 30% impervious cover. Stormwater system elements include stone seepage pits for roof runoff and a sub-surface conveyance system, sized for the 100-year storm with connection to an off-site drainage system with creek outfall. This system uses open-bottom catch basins with perforated piping. Otherwise, however, the system is conventional.

Remarks: nonpoint source pollutant generation will be as follows:

Total phosphorus	15 lbs / yr
Total nitrogen	118 lbs / yr
COD	2,110 lbs / yr
BOD	302 lbs / yr
Zinc	2 lbs / yr
Lead	1 lbs / yr

Although special effort has been taken to make sure that the stormwater drainage system itself is adequate to store the peak 100-year storm runoff from the proposed development, quality issues are not adequately addressed and will result in additional water quality problems. Although some recharge can be expected to occur here, the bulk of the stormwater will still be stream discharged after some detention, with attendant minimal water quality impacts. Again, we would advocate first that a serious look be given to re-configuration of units, clustered and at even higher densities to allow for common parking areas with sub-surface recharge and other infiltration practices as well as managed operating practices. If single-family fee-simple is dictated here, then greater use should be made of infiltration basins and trenches integrated into overall grading-drainage-landscaping planning so that drainage from maintained areas is collected and infiltrated. Drainage from driveways could also be handled in this manner with drainage from roads directed into retention basins or wet ponds. Without modifications, this site will produce significant NPS impacts.

CASE STUDY 16. WATERFRONT COMMERCIAL

Waterside Plaza: Edgewater, Bergen County; 92,750 sq. ft. on 7 ac. site along Hudson River. The percent imperviousness is not provided, although it appears to be quite high. The stormwater is collected and then sent through oil separation devices before being discharged into the Hudson River.

Remarks: The project engineers spent considerable effort arguing that, because of the proximity to the River and tidal dominance, overall flooding concerns "downstream" were not relevant. This is correct from a hydraulic perspective, but water quality issues are significant, although receiving waters are currently of poor quality. Also, it was argued that because of the high water table and floodplain conditions, basins and other infiltration devices would not be appropriate, as set out in current Coastal Policies themselves. Therefore, the special separating chambers are about the only option remaining for intervention between runoff and receiving waters, if we assume that this use is to be developed at this density and at this location. In general, the effectiveness of oil separating chambers has not proven to be great. The major question here then is does this particular design appear to be a good one and will the numerous oil separation chambers be properly maintained in the future?

Several concepts are recommended here. First, the roof runoff should be conveyed to receiving waters, to reduce sheet flow of pollutants from impervious surfaces. Second, although SHWT conditions may be limiting, some consideration should be given to the use of pervious material, possibly with a vegetative buffer along the water's edge. Third, a commercial site such as this could prevent much of it's pollution potential with good housekeeping, and site maintenance should be built into the permitting process. This should include cleanout of all stormwater inlets. Finally, the concept of off-site mitigation should be considered, with an equivalent reduction provided to offset the NPS impact of the proposed facility.

CASE STUDY 17. SINGLE-FAMILY RESIDENTIAL

The Woodlands: Dover Township, Ocean County; 64.5 acres with 13% impervious cover; 88 single-family detached units proposed. The proposed stormwater system includes a system of perforated and conventional piping that discharges onto two rip-rap pads, then to overland flow, and then into adjacent wetlands.

Remarks: Based on summary calculations, nonpoint pollutant loadings would be as follows:

Total phosphorus	23	lbs / yr
Total nitrogen	176	lbs / yr
COD	3,130	lbs / yr
BOD	448	lbs / yr
Zinc	3.3	lbs / yr
Lead	1.6	lbs / yr

As with the Stemark development above, we would first advocate that the basic concept of development be questioned--single-family fee-simple with individual lot ownership, landscaping, and maintenance. From a nonpoint source perspective, this approach to housing the approximately 250 persons who would live in these units is undesirable. During the construction and operation phases, significant amounts of pollutants will be discharged into adjacent waters. Because of the very nature of the unit type here, we can expect that applications of fertilizers, herbicides, and pesticides will be problems in the future. The point is to first design the development so that the potential for future pollution is minimized. That means minimizing disturbance of existing vegetation where it exists and tightly clustering new development at any particular density. It means also the re-vegetation of disturbed areas with native species and in such a way that ongoing maintenance is minimized. Ideally, this approach translates into housing that is as "vertical" as possible with massed areas of paving (parking and roadways) where infiltration techniques such as porous paving/underground recharge beds and wet ponds and infiltration beds can be readily adapted. This plan reflects none of these concepts, and represents significant NPS impacts as conceived.

If these accommodations cannot be made, then the subdivision should be clustered with a master landscape and drainage plan designed to maximize natural filtration and recharge. As a final recourse, lot-specific measures should be employed such as infiltration trenches and naturally-vegetated swales to minimize runoff and nonpoint source loadings. In the case of the Woodlands, if this development concept is to be employed here, we would argue, for example, for dry wells to

APPENDIX B.

CASE STUDY
MINIMUM DEVELOPMENT/MINIMUM MAINTENANCE
BALD HEAD ISLAND, NC

CASE STUDIES

MINIMUM DISTURBANCE/MINIMUM MAINTENANCE DEVELOPMENT

Bald Head Island

"It was North Carolina's first war of the coastal environment, and it raged for nearly two decades. Environmentalists fought for preservation. Developers sought a posh resort with a population as high as 180,000 and even an international airport. The prize was Bald Head Island, which, along with Middle and Bluff Islands, makes up the Smith Island complex off the Brunswick County coast."

"In the end, neither side won. Those who wanted the island to become a state park still shake their heads over a paradise lost. But there is a consolation, they say. If the island had to be developed, its latest owner has created an acceptable blend of preservation and change. The developer agrees. 'Bald Head Island should have been preserved,' says Kent Mitchell. 'But if it had to be developed, then I'm the best one to do it.--without question.'"

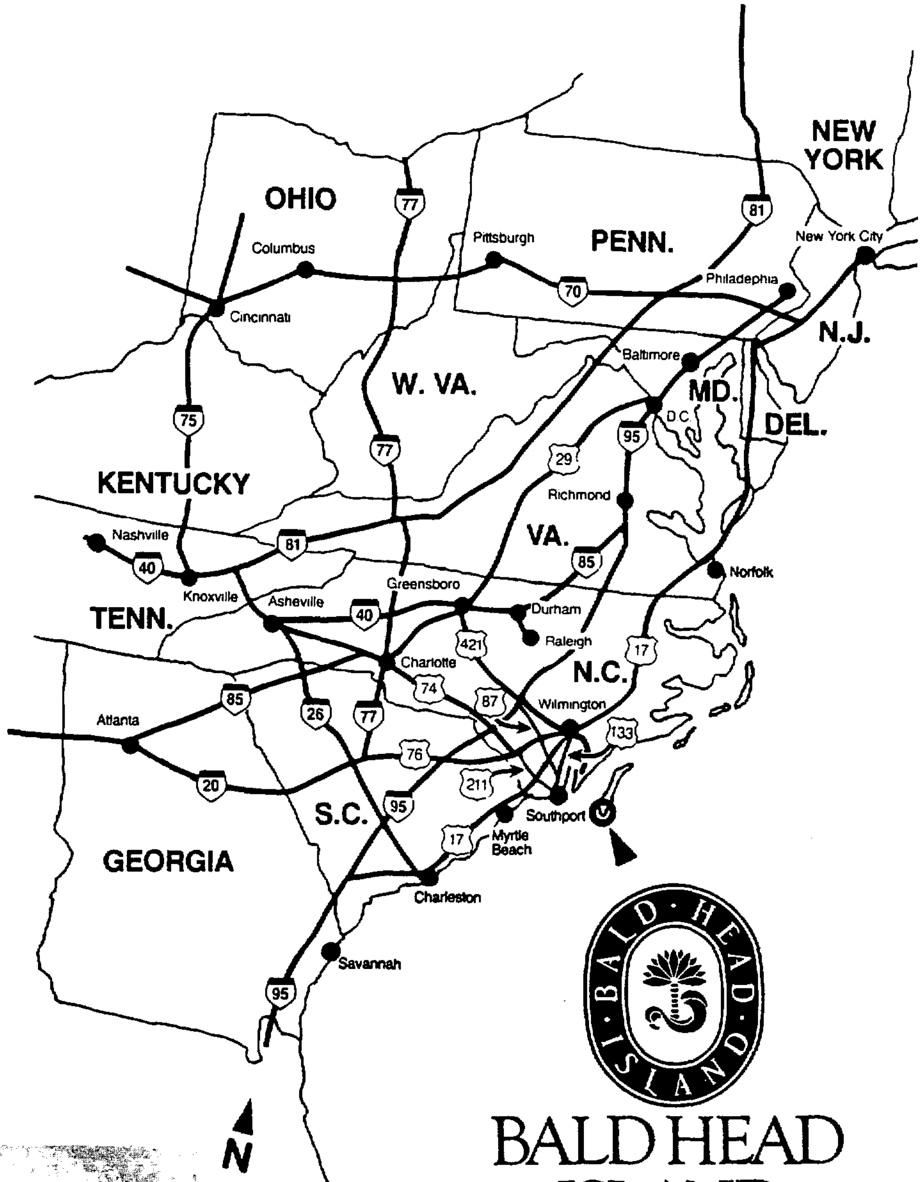
"On Bald Head, nature has united an odd combination of temperate and tropical life. Large stands of palm trees grow farther north than they're supposed to, and temperatures average several degrees warmer than on the mainland just three miles away. At one time, Bald Head claimed the state's largest maritime forest. It is still the most popular nesting ground in the state for the endangered loggerhead sea turtle."

"In 1983, Kent Mitchell and his brother visited the island. They convinced their father, another wealthy Texan, to buy the island....Kent Mitchell, a Harvard architecture graduate, found himself caught almost immediately between his belief that the island should have been preserved and his desire to turn it into a model resort. 'We fell in love with the island before we bought it. We still love the island, and that's the tough battle,' Mitchell says. 'It's a tough compromise between making money and maintaining the balance with the environment.' The result has been Mitchell's own version of a beach community."

"This is Mitchell's first big project, but such developments are nothing new for his family. In addition to building a planned city of 200,000 people outside of Houston, the Mitchells have been active in a push to restore a historic area of Galveston. When Mitchell took over operations at Bald Head, much of the first stage of development was complete. He inherited an inn, a restaurant, and 18-hole golf course and 40 to 60 townhouses and villas. Some private homes had also been built. With that stage nearly complete, Mitchell is ready to begin a second stage that will include 600 acres of the eastern portion of the island. By the time the Bald Head project is complete in 15 years, about 1,600 acres of the 3,000-acre private tract will have been developed. Although about a third of the first stage was condominiums, about 90 percent of the second stage will be single-family homes."

"Bulldozing lots is forbidden. Many homes are tucked between the trees, and residents are encouraged to landscape with native plants....Except for the occasional inconvenience of living on a remote island...,property owners are happy with their piece of paradise."

(Coast Watch, November 1987, University of North Carolina Sea Grant College Program, Raleigh, NC)



BALD HEAD ISLAND

AT CAPE FEAR

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Figure B-1. Regional Location of Bald Head Island

Bald Head Island offers an excellent example of the potential benefits to be reaped from minimum disturbance/minimum maintenance development. Dan Cutler, chief of planning for the developer, explains that development is tightly controlled throughout the island. Property restrictions specify that "...No building, dwelling, accessory building, fence or other structure shall be erected, placed or altered on any lot or parcel within the Property until the proposed building plans, specifications, elevations, exterior color or finishing, plot plan (showing the location of such building or structure, drives and parking areas) and construction schedule shall have been approved in writing...." (Property Restrictions, 1984). All new site plans are carefully reviewed to guarantee that maximum existing topography and vegetation are preserved and minimum re-landscaping and upkeep will be necessary. Views, privacy, and other factors are also taken into account. The owners association has developed a list of indigenous plant species to be used where replanting and re-landscaping is necessary. Removal of any trees with 3 inch diameter or more must be individually permitted, though the planning review process is designed to avoid this problem in the vast majority of cases. The association also specifies pesticides and herbicides which may be applied, although any such chemical use is discouraged as a matter of policy. Through use of native species, such chemical use is minimized by practice as well. Lawns of any type--and therefore customary lawn maintenance such as fertilizer applications--are strongly discouraged, though not specifically forbidden. Several building types have resulted (Figures B-2 and B-3).

The essence of the minimum disturbance/minimum maintenance philosophy is set out in Bald Head's Design Guidelines: Recommendations and Standards, where great importance is given to conservation of the vital ecological relationships which exist on the island:

> "The sensitive relationships we have just described are something you as a property owner on Bald Head Island should take special effort to preserve. This means not only protecting the existing flora on your property, but increasing the productive natural systems of your own particular mini-environment. 'Natural' landscaping can help you accomplish both ends. This means, for the most part, planting and allowing the native plants to flourish of their own accord. Most likely, this is opposed to spending a lot of time and money establishing new grass, new sod and ornamental plants. Letting nature run its course does not mean total abandonment of planting maintenance. Rather, it will mean a controlled and guided landscape in character with the charm and beauty of Bald Head Island."

> "First, after determining the location of the house on the lot, limits of construction should be established. Particularly sensitive areas should be protected with strategically placed snow fences to ensure equipment and materials from damaging plant life. A preconstruction discussion with your builder on site can be valuable for reducing needless damage and removal of the topography and vegetation. Progress reviews are equally valuable to inventory damage and responsibility."

> "A successful landscape plan is composed of a number of elements that, with quality design and execution, contribute to a unified marriage of the natural environment and man-made elements introduced to the site. These introduced elements will be reviewed by the Bald Head Architectural Review Board for approval. The landscape plan, likewise, will be reviewed by the Board for effectiveness...."

> "The cutting of the forest canopy or the thinning of its understory may expose remaining vegetation to harmful salt laden winds, resulting in damage. For this reason, cutting and thinning should be kept to an absolute minimum (especially in the spring and summer), leaving the vegetation for buffering, privacy and landscaping definition. The 'leading edge' of the maritime forest is especially sensitive as it protects the remaining forest from the 'dominoe effect' of saltspray dieback. This edge should never be disturbed."

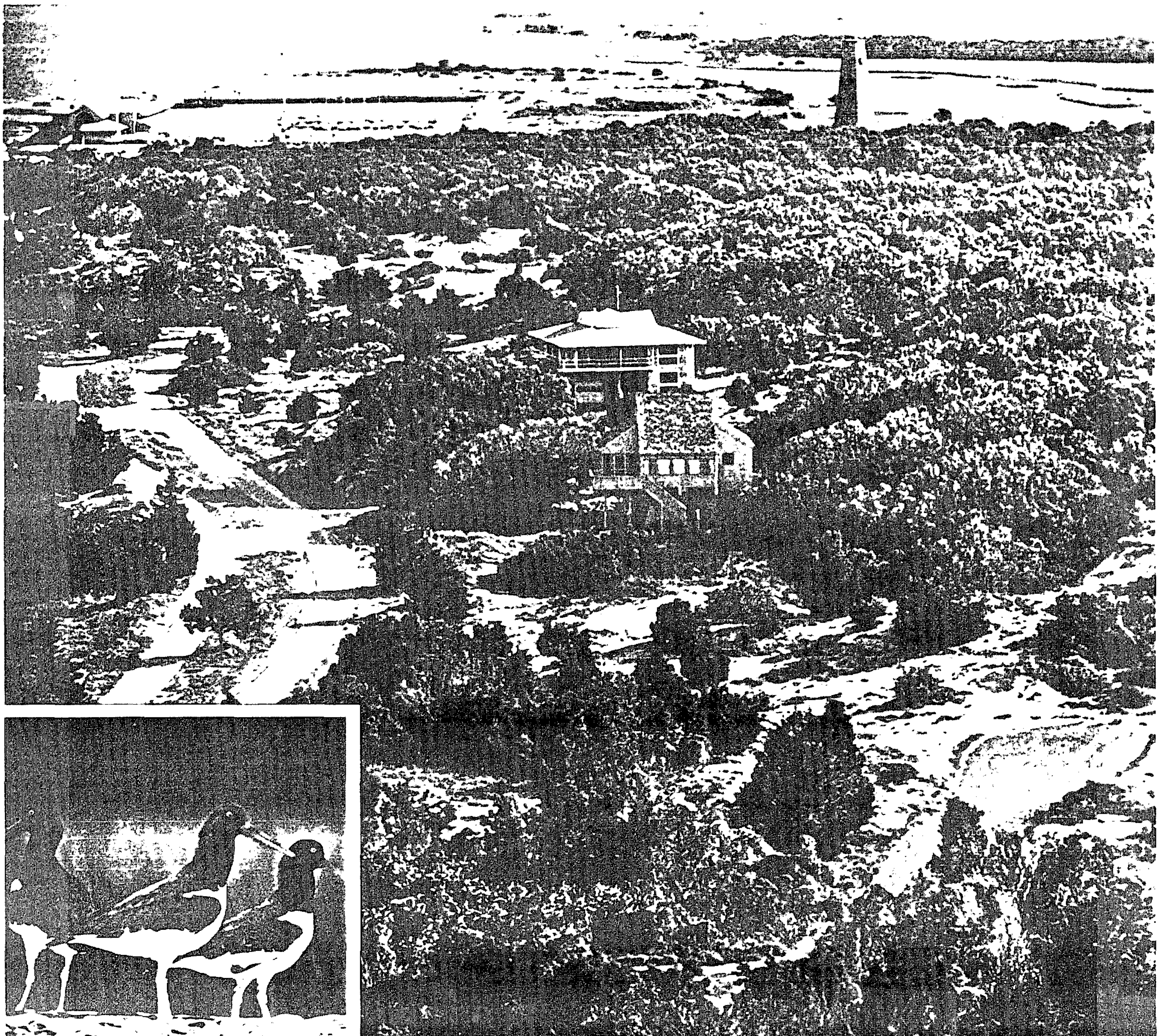
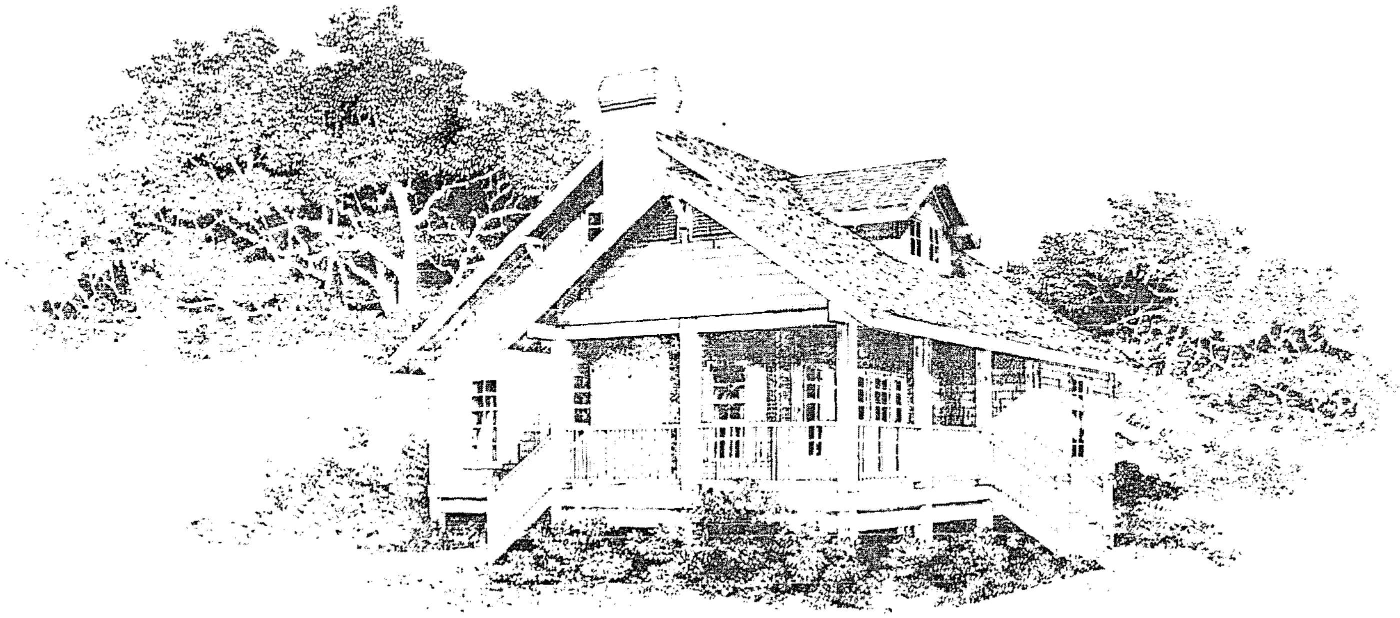


Figure B-2. Panorama of Bald Head Island Development



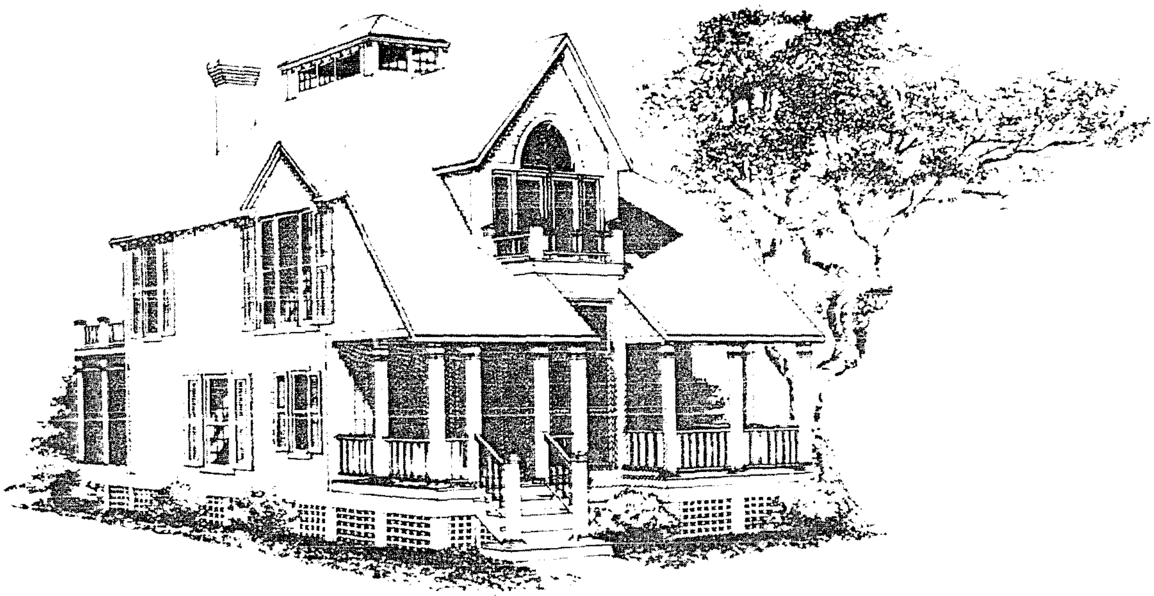
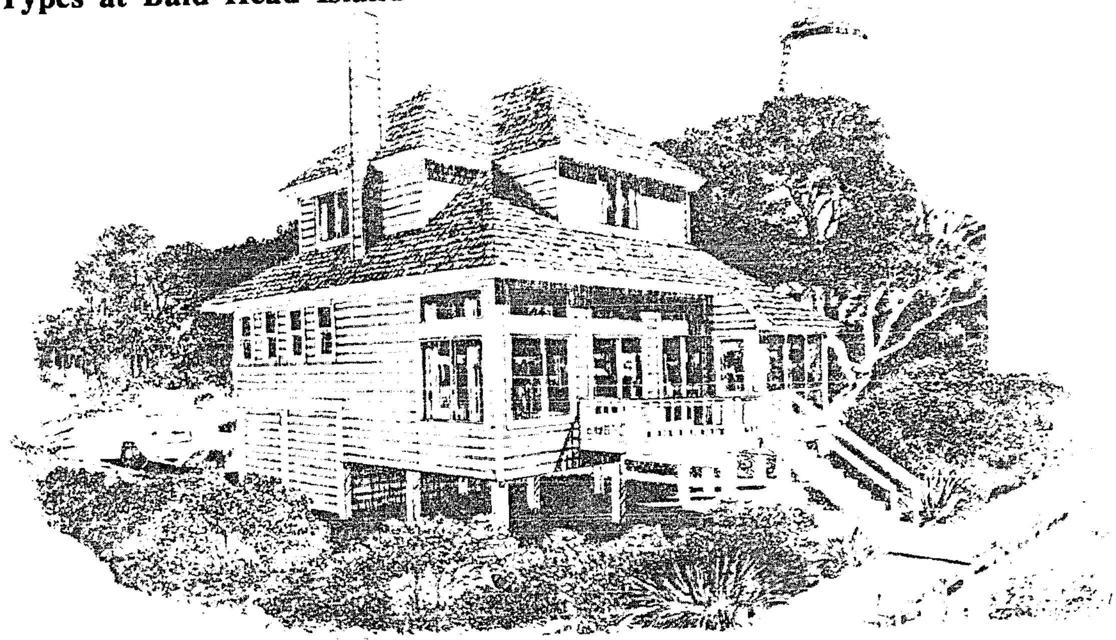


Figure B-3. Building Types at Bald Head Island



"The use of native grasses for groundcover is highly encouraged. Most native grasses are not available commercially and will take several years to establish unless hand collected and planted. However, this is not difficult....Sod and high maintenance lawns are highly discouraged."

"The natural landscaping approach should concentrate your planting efforts adjacent to the house, especially near the entry. The more ornamental plants, if used correctly, will provide a transition from the natural character of the site to the man-made structure of the home. The groundcovers should begin this transition, which should progress to larger shrubs closer to the house. For maximum appeal try to mix textures and colors but do keep the plan simple. A better effect can be achieved from using quantities of a few species rather than a few plants each of many species. Straight line planting is discouraged - planting should achieve a staggered, grouped effect as if grown naturally."

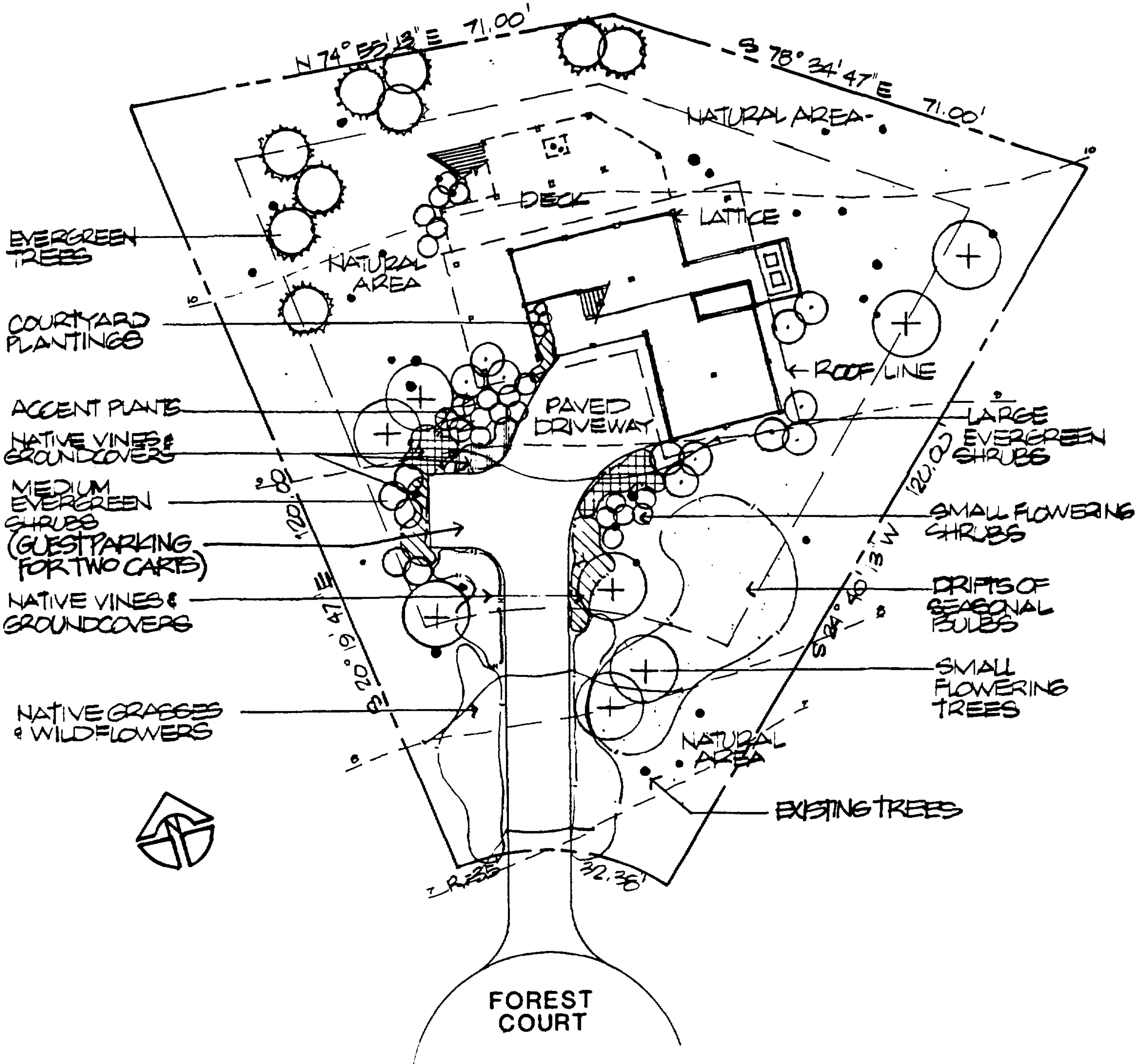
"Finally, a word on plant maintenance. A successful landscape plan for your island home should be one that virtually eliminates most time consuming maintenance. Pruning and mowing are all but forbidden! An occasional clip of a wayward vine or unwanted weed and keeping the lot free of trash should be all that is necessary. An annual mow will keep those natural grass areas from succession into shrubs, if desired."

Porous surfaces (turfstone, pea gravel, marl) are recommended for driveways, turnarounds, and parking areas. Homes do not necessarily have to be parallel to the street front. Site grading shall be kept to a minimum; the drainage system should exploit the natural grade and vegetation. Typologies of a dune lot and forest lot have been developed (Figures B-4 and B-5). Cutler reports that Bald Head's approach has become quite popular. Though no system is without flaws, owners apparently have embraced minimum disturbance/minimum maintenance enthusiastically and, as a matter of fact, have become the most vigilant enforcers of the system themselves.

The Bald Head Island case study is curious because it has evolved for a variety of environmental reasons which are not directly relevant to nonpoint source water quality loadings in coastal waters. Threatened and endangered species were major concerns. Preservation of the dunes and the maritime forest and their critical natural functions were concerns. In terms of water, Bald Head officials were most concerned about other types of water quality impacts, such as the potential for the contamination of the aquifer which is so close to the surface here and which provides Bald Head with its water supply (as the result of this concern, the natural filtration of stormwater runoff has been and continues to be of great concern; for example, in order to purify runoff from the golf course, a system of receiving lagoons or wet ponds has been constructed and stocked with special high algae-consuming fish species). In any case, future development here also will have to comply with North Carolina's new coastal water quality program which has a major nonpoint source emphasis. Thus, it is somewhat ironic that the Bald Head model should be so ideally suited for the New Jersey coastal nonpoint program. Nevertheless it is an excellent model, and although there certainly are some barrier island and other situations where such approaches may not be feasible, minimum disturbance/minimum maintenance should be able to be applied broadly in New Jersey coastal drainage..

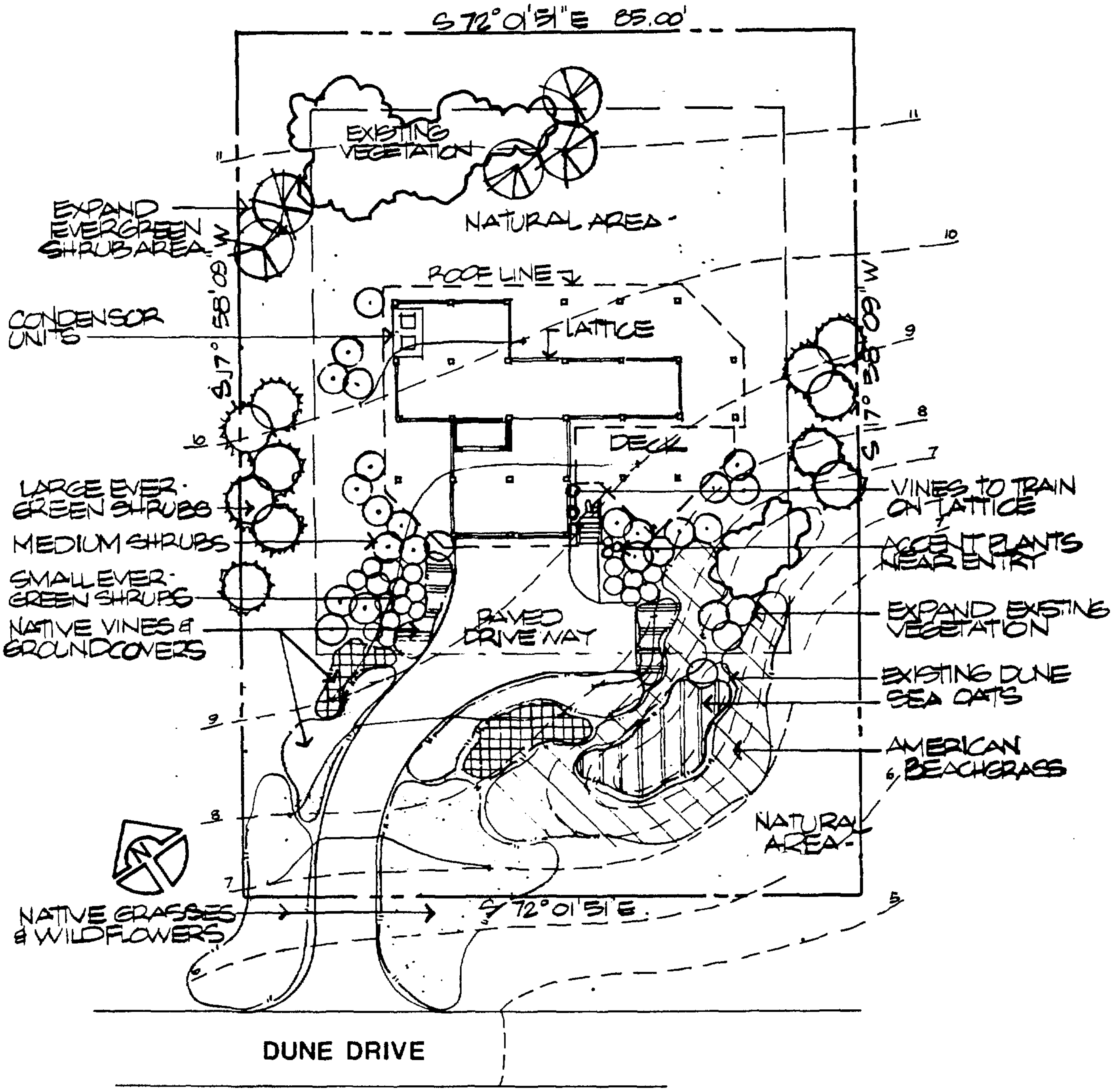
Bald Head in the end shows us that it can be done--that minimum disturbance/minimum maintenance is a viable approach to development at least in many contexts within New Jersey coastal drainage. Bald Head also demonstrates that such an approach carries with it enormous additional environmental benefits that extend well beyond nonpoint source water quality issues and that reinforce the many ecological values being threatened there.

Figure B-4. Typical Dune Lot Planting Plan at Bald Head Island



THIS PLAN REFLECTS A HYPOTHETICAL LOT, HOUSE AND LANDSCAPE DESIGN. EACH SITE IS UNIQUE AND WILL REQUIRE SPECIAL CONSIDERATIONS. FURTHER INFORMATION IS REQUIRED THAN WHAT IS SHOWN FOR A COMPLETE SUBMITTAL PACKAGE FOR THE ARCHITECTURAL REVIEW BOARD.

Figure B-5. Typical Forest Lot Planting Plan at Bald Head Island



THIS PLAN REFLECTS A HYPOTHETICAL LOT, HOUSE AND LANDSCAPE DESIGN. EACH SITE IS UNIQUE AND WILL REQUIRE SPECIAL CONSIDERATIONS. FURTHER INFORMATION IS REQUIRED THAN WHAT IS SHOWN FOR A COMPLETE SUBMITAL PACKAGE FOR THE ARCHITECTURAL REVIEW BOARD.

The Woodlands

The Woodlands is a "new town" 27 miles north of Houston TX, conceived and planned over 20 years ago during HUD's Title VII "new town" program. The land involved encompasses approximately 25,000 acres with an ultimate town build-out population at from 150,000 to 200,000 persons. Ultimately the Woodlands will consist of six villages with 55,000 residences and 3,400 businesses with nearly 100,000 jobs. Currently, there are approximately 25,000 residents, with 325 businesses and 7,000 jobs created. Interestingly, the Woodlands was also developed by the Mitchell family who wanted to create an entire community that harmonized with the environment and provided a superior quality of life. Although a large percentage of the Woodlands is itself to be reserved for open space, the most important feature of the Woodlands is the manner in which development is to take place. George Mitchell, father of Kent Mitchell and head of Mitchell Energy and Development Corporation, set out first to preserve the forest's scenic beauty and natural drainage. He hired Ian McHarg, noted ecologist and landscape architect at the University of Pennsylvania, to undertake an environmental impact analysis and then to incorporate analysis findings into the Woodlands master plan. Critical here was the preservation of the natural drainage system of the forest, important in order to maintain the natural groundwater recharge of the aquifer which is the basis for Woodlands water supply. Also critical is the maintenance of groundwater levels in order to supply forest vegetation with adequate water supply, if the life of the forest is to be guaranteed--the basic amenity which was the rationale for the Woodlands in the first place. Also critical was the safe management of stormwater itself, given the Houston area's considerable rainfall--a traditional approach to development would have generated vast amounts of additional stormwater runoff; infrastructure for this stormwater was estimated at one point to cost $80,000,000 itself. According to th Woodlands Corporation, effectiveness of the natural drainage approach has been remarkable--"During the downpours from Hurricane Alicia in August of 1983, the community remained undamaged from runoff while extensive areas elsewhere in the region were flooded. And in the summer of 1987 the community again came through extensive downpours without flooding." ("A Master Plan for Effective Drainage," The Woodlands Corporation)

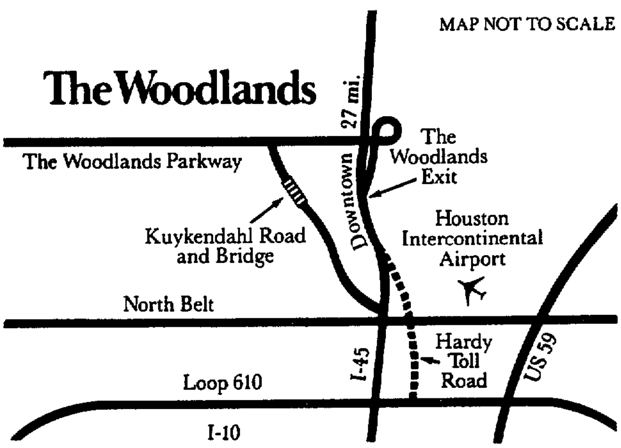
As with Bald Head Island, the Woodlands is controlled by a set of covenants, restrictions, easements, charges, and liens. A development standards committee has been formed which establishes standards for landscaping for the "...preservation of trees and other natural resources and wildlife to protect and encourage the preservation of the ecological balance of the Property." ("Covenants Restrictions, Easements, Charges and Liens," p. 28) In "A Residents' Guide to Landscaping in The Woodlands," the theory behind natural landscaping is set out:

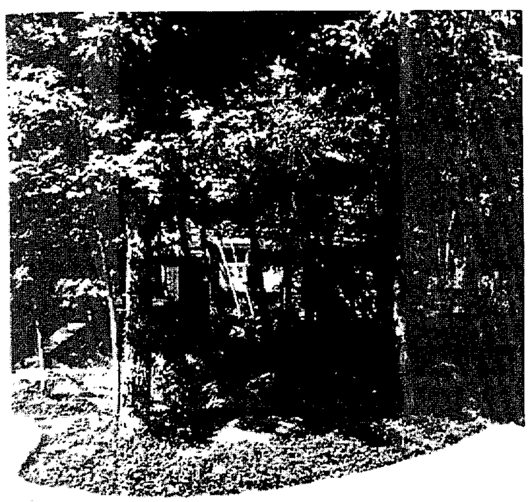
> "If you moved to The Woodlands to be close to nature you are not alone. Many homeowners have found that living in a forest is a unique experience not found in most man-made environments where nature is in a constant state of decline. Now, what happens when you blend your home into the forest? For one thing, you are one of the privileged few who can observe the silent wonders of nature from the comfort of your own home. Squirrels, birds of all descriptions and other forest creatures will be your nearest neighbors. You will be awakened in the morning by the soft sounds of life in the forest. For another thing, you are increasing the value of your property by improving its environment. While the value of your property is a long-term consideration, there are some more immediate benefits which you should consider.
>
> "*Privacy*. Natural native growth can act as a visual screen and a sound baffle between you and your neighbor or you and a public area."

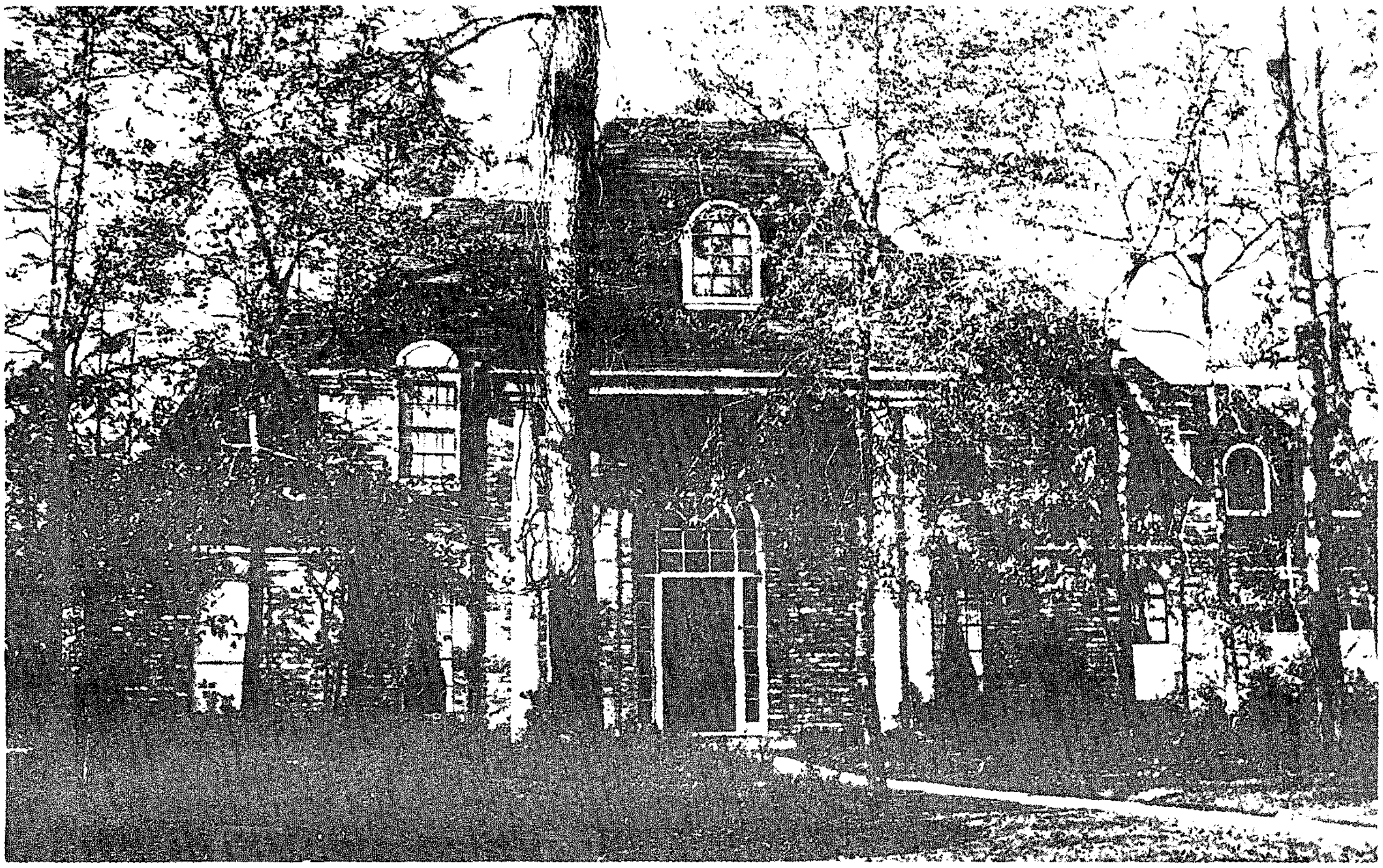
A Residents' Guide to Landscaping in The Woodlands

Dedicated to
Our Commitment
to the Forest

Figure B-6. The Woodlands







COVENANTS, RESTRICTIONS, EASEMENTS,

CHARGES AND LIENS

OF

THE WOODLANDS

Figure B-7. The Woodlands

Figure B-8. The Woodlands

"*Energy Conservation*. The Federal Energy Administration reports that landscaping can be beneficial in reducing heat gains or losses by reducing direct solar radiation and by reducing air leakage (by lowering the wind velocity and by reducing the heat transmission of windows). It was also reported that air conditioning in a fully-shaded house works only half as much as that in a house with walls and roof exposed to the sun."

"*Water Conservation*. Sodded lawns have a much greater water demand than natural bed areas."

"*Shade*. Besides keeping your home cool in the summer, your naturally landscaped yard will be a shaded haven for your and your family throughout the hottest months of the year."

"*Landscape Maturity*. Native plants will mature faster than non-native shrubs that must be pruned and manicured. Your landscape will have that "seasoned" look in a relatively short time."

"*Convenience*. Quite simply, it's easier to maintain a naturally landscaped home. Only the sodded areas will need to be mowed. Natural pine barked beds, once established, will require nothing more than occasional weeding, debris removal, and remulching."

"*Wildlife*. The forest provides shelter and food for birds and other residents of the forest that would not normally be present in a conventionally landscaped yard."

"*Beauty*. You will be pleasantly surprised by the natural beauty and seasonal variations of your natural landscape. The forces of nature will create a perfect composition of color, texture, form, and line with very little effort on your part. If all we have in our yard is an urban park-like environment with mowed lawns, manicured shrubbery, and no young trees, we are hastening the decline of the forest that remains. How long would it be before the older trees eventually die and no forest is left at all?"

As in the case of Bald Head Island, a very specific set of steps is recommended for the site development and landscaping process at the Woodlands in order to make the minimum disturbance/minimum maintenance concept workable. At the heart of the approach is an understanding of and respect for the various layers of the forest zone: the forest floor, the understory, and the canopy. Woodlands planners have gone to great lengths to make the concept work.

"Any easy way to preserve your own reforestation zone is to leave the areas unsodded and simply spread pine bark or pine needles to help restore the forest floor that may have been disturbed during the construction process. As mentioned earlier, your zones should have a gentle and continuously curving edge where the lawn grass ends and the zone begins. The maintenance of a 'clean' edge will help prevent encroachment of choking lawn grasses and reinforce its appearance as a purposeful reforestation zone rather than an area of neglect."

"If you have a yard with little natural forest remaining, there are ways to recreate a living forest. Here your imagination is the limit. Creating a reforestation zone is similar to preserving a reforestation zone but for the obvious fact that, with the exception of the existing canopy trees, you are starting from scratch. Using your plan sketch as a guide, you can now stake out the areas where your new forest will begin. A garden hose laid out on the ground works well in visualizing where the reforestation zones will be located and allows you to adjust their location, shape, and size to your own desires. Once you have determined the location, it's time to get busy restoring the forest."

"If most of the canopy and understory on your lot are missing, then the creation of your reforestation zone may be more involved. But with some patience, creating a forest will be an ongoing activity that can provide much enjoyment and a feeling of accomplishment. Start by adding selected canopy trees as appropriate where you have no canopy or where you would like to eventually have a more dense forest character. In between the canopy trees you might add some sun-tolerant understory trees and shrubs. As your canopy matures and a balanced forest evolves, you can fill in with understory plants that respond positively to more filtered sunlight."

"The foundation of your new forest area will of course be the forest floor mentioned earlier. Adding a two to three inch layer of pine bark or decomposed leaves and pine needles will emulate the natural forest floor and will minimize the invasion of undesirable weeds. With the forest floor in place, you should give Mother Nature a chance to show you just how much plant life will volunteer by the end of the first growing season. As the new seedlings begin to surface, the process of natural reforestation is underway. In a conventionally landscaped yard these seedlings would have been covered with sod and never been given a chance to become the forest of tomorrow."

The Guide generally points to the recommendation that less is more, when it comes to maintenance practices. For example, pruning need only be selective. Leaves and needles as they drop should either be allowed to remain on the forest floor, or if on some other area, then spread and redistributed onto nearby forest areas as natural mulch. Fertilizer applications are discouraged. If native species are used and properly planted and mulched, fertilizer should not be needed. Also recommended here is the use of pilotis or raised column foundations or post and beam construction, requiring no fill at all. Such techniques eliminate or minimize need for fill and therefore reduce the amount of area which is disturbed during the construction process. Although initial outlays for these alternative techniques can be greater than for conventional slab construction, savings in minimized fill or reduced re-landscaping costs can balance additional costs. Porous paving is recommended for parking areas in both nonresidential and residential areas; clustered parking and the general sharing of parking areas is also encouraged at the Woodlands, where feasible.

We should note here that there apparently has been some divergence at the Woodlands from some of the initial environmental planning principles. According to William Kendricks, director of landscape management at the Woodlands, there are some areas where for any number of reasons the natural drainage system is not being relied upon. Some residents do insist on lawn development. Nevertheless, even with these imperfections, the Woodlands represents a remarkable step forward in the progression toward minimum disturbance/minimum maintenance development. Interestingly, because of its non-seasonal nature, it provides evidence that this seemingly radical approach to development can not only peacefully coexist with year-round "normal" suburban/urban living, but in fact can enhance such a life style.

As with Bald Head Island, the minimum disturbance/minimum maintenance approach to development evolved at the Woodlands for reasons other than nonpoint source water quality pollution. As one reviews background planning literature surrounding the project, the importance of maintaining the natural vegetation--the forest--to accommodate drainage needs, to provide for adequate groundwater recharge, to promote stream base flow, to minimize soil subsidence, and to accomplish any number of other important people-related and environmental needs emerges clearly. Water quality considerations appear to have been secondary in importance. Nevertheless, as with Bald Head Island, the Woodlands development does have compelling nonpoint source water quality impact.

BIBLIOGRAPHIES

BIBLIOGRAPHIES

I. New Jersey Water Quality

ARH, (undated). *Stormwater Management: A Case Study of Problems and Regulatory Framework in Egg Harbot Township, Atlantic County, New Jersey, Volume I.* Adams, Rehmann, and Heggan Assoc., Inc., Hammonton, New Jersey, for the The Atlantic County Water Quality Management Program, Atlantic County, NJ

Barton, C., E. F. Vowinkel, and J. P. Nawyn, 1987. *Preliminary Assessment of Water Quality and its Relation to Hydrogeology and Land Use: Potomac-Raritan-Magothy Aquifer System, New Jersey.* U.S.G.S. Water-Resources Investigations Report 87-4023. USGS, West Trenton, NJ

Berry, K. and P. Olsen, 1981. *Summary of Phytoplankton Dynamics and Bloom Incidence in New Jersey Coastal Waters, 1981.* New Jersey Dept. of Environmental Protection, Div. of Water Resources, Bureau of Monitoring and Data Mgmt., Biological Services Unit, NJDEP, Trenton, NJ

Berry, K. and P. Olsen, 1982 *Summary of Phytoplankton Dynamics and Bloom Incidence in New Jersey Coastal Waters, 1982.* New Jersey Dept. of Environmental Protection, Div. of Water Resources, Bureau of Monitoring and Data Mgmt., Biological Services Unit, NJDEP, Trenton, NJ

Cabelli, V. J., 1983. *Health Effects Criteria for Marine Recreational Waters.* Office of Research and Development, USEPA, Wash., DC.

DeMaster, D. J., R.B. McKinney, C.A. Nittrouer, and K.W. Thorbjarnarson, 1984. *Sediment Accumulation in a Back-Barrier Lagoon, Great Sound, New Jersey.* North Carolina State Univ. Dept. of Marine, Earth, and Atmospheric Sciences, Raleigh, NC.

Draxler, R. Waldhauer, A. Matte, and J.B. Mahoney, 1984. *Nutrients, Hydrography, and Their Relationship to Phytoflagellates in the Hudson-Raritan Estuary.* U.S. Department of Commerce, NOAA, National Marine Fisheries Service, Northeast Fisheries Center, Highlands, NJ, in Bull. New Jersey Acad. Sci., Vol. 29, No. 2, pp. 97-120, Fall, 1984.

Durand, J. B., 1984. *Nitrogen Distribution in New Jersey Coastal Bays,* Chapter 2 in Lecture Notes on Coastal and Estuarine Studies, Ecology of Barnegat Bay, N.J., by M. J. Kennish & R. A. Lutz, Ed., Springer-Vertag, New York, NY.

Durand, J. B., 1979. *Nutrient and Hydrological Effects of the Pine Barrens on Neighboring Estuaries.* Ch. 11 in Pine Barrens, Center of Environmental Studies, Rutgers Univ., Camden, NJ.

Fusillo, T., J. C. Schornick, Jr., H. E. Koester, and D. A. Harriman, 1980. *Investigation of Acidity and Other Water-Quality Characteristics of Upper Oyster Creek, Ocean County, New Jersey.* U.S.G.S. Water-Resources Investigations 80-10, Water Resources Division, U. S. Geological Survey, Trenton, NJ

Fusillo, T., J. J. Hochreiter, Jr., and D. G. Lord, 1985. *Distribution of Volatile Organic Compounds in a New Jersey Coastal Plain Aquifer System.* Groundwater, 23(3), May-June 1985.

Gray , T.S. and S.T. Williams, 1971. Soil Micro-Organisms. University of Liverpool, Oliver and Boyd, Edinburgh, EH1, 1YL.

Ketchum, B.H., 1955. *Phytoplankton Nutrients in Estuaries*. Woods Hole Oceanographic Institution, Woods Hole, MA, in Estuaries: Nutrients and Biological Production.

Kinsey, D. N., 1986. *Lessons From the New Jersey Coastal Management Program*. Div. of Coastal Resources, NJDEP, Trenton, NJ

Kish, G., J. A. Macy, and R. T. Mueller, 1987. *Trace-Metal Leaching from Plumbing Materials Exposed to Acidic Ground Water in Three Areas of the Coastal Plain of New Jersey*. U.S.G.S. Water-Resources Investigations Report 87-4146, Water Resources Division, U. S. Geological Survey, West Trenton, NJ

Lee, G. F., and R.A. Jones, 1987. *Impact of Reducing P Loads from Domestic Wastewaters on Algal-Related Water Quality of Northern New Jersey's Coastal Waters*. New Jersey Inst. of Tech., Dept. of Civil and Env. Eng., Newark, NJ

Liebig, J., 1840. *Chemistry in its Application to Agriculture and Physiology*. Taylor and Walton, London (4th Ed., 1847).

Mahoney, J.B. 1979. *Environmental and Physiological Factors in Growth and Seasonal Maxima of the Dinoflagellate Ceratium Tripos*. Bull. New Jersey Acad. Sci., Vol. 24, No. 1, pp. 28-38, Spring, 1979.

McCormick, J. and L. Jones. 1973. *The Pine Barrens - Vegetation, Geography*. Res. Rpt. No. 3, N.J. State Museum, Trenton, NJ

Mansue, L.J., and P.W. Anderson , 1978. *Effects of Land Use and Retention Practices on Sediment Yields in the Stony Brook Basin, New Jersey: Sedimentation in Small Drainage Basins*. U. S. Geo. Survey, Water Supply Paper 1798-L, West Trenton, NJ

McBride, K.K., 1984. *Decontamination of Ground Water for Volatile Organic Chemicals: Select Studies in New Jersey*. Div. of Water Res., N. J. Dept. of Env. Prot., Trenton, NJ

MCPD, 1983. *Lake Carnegie Eutrophication Analysis*. Mercer Co. Plg. Dist., Mercer Co.,Trenton, NJ

MCPD, (undated) *Mercer County Stream Surveillance Report Finds Toxic Pollution in Shabakunk Creek and Little Bear Brook*. Mercer County Stream Lines. Mercer County Plg. Dist., Trenton, NJ

MCPD. 1980. *Toxics and Water Supplies: Learning Our Limits*. Mercer County Stream Lines, Spring 1980, Trenton, NJ

Mueller, J.A., J.S. Jeris, A.R. Anderson, and C.F. Hughes, 1976. *Contaminant Inputs to the New York Bight*. Marine EcoSystems Analysis Program Office, NOAA, Boulder, CO

Mueller, J.A., T.A. Gerrish, M.C. Casey, 1982. *Contaminant Inputs to the Hudson-Raritan Estuary*. National Oceanic and Atmospheric Administration, Office of Marine Pollution, Boulder, CO

Nemickas, B., 1976. *Digital-Simulation Model of the Wenonah-Mount Laurel Aquifer in the Coastal Plain of New Jersey.* U.S.G.S., Open-File Report 75-672, U. S. Geological Survey, Trenton, NJ

NJDEP, 1973. *Studies of the Upper Barnegat System.* Final Report, Proj. No. 3-137-R-2, Div. of Fish, Game and Shellfish, Bureau of Fisheries, Nacote Creek Research Station, NJDEP, Trenton, NJ

NJDEP, 1979. *Comparison of Natural and Altered Estuarine Systems. Analysis and Field Data.* Ctr. for Coastal and Env. Studies, Rutgers Univ. and NJDEP, Trenton, NJ

NJDEP. 1981. *Water Quality Survey, Honey Brook Lake.* Division of Water Quality, Bureau of Monitoring and Data Management, NJDEP, Trenton, NJ

NJDEP, 1982. *Summary of Phytoplankton Dynamics and Bloom Incidence in New Jersey Coastal Waters, 1981.* K. Berry and P. Olsen, Bio. Serv. Unit, NJDEP, Trenton, NJ

NJDEP, 1983. *PCBs in Selected Finfish Caught Within New Jersey Waters, 1981-1982 (With Limited Chlorodane Data).* T. J. Belton and B. E. Ruppel, Off. of Science and Res. and K. Lockwood and M. Boriek, Div. of Fish, Game and Wildlife, NJDEP, Trenton, NJ

NJDEP, 1984. *Water Quality Study: Impacts of Marine Activities.* Division of Water Resources, Bureau of Marine Water Classification and Analysis, NJDEP, Trenton, NJ

NJDEP, 1986a. *Responsiveness Summary for the Proposed Priority System and Project Priority List for Fiscal Year 1987.* Division of Water Resources, NJDEP, Trenton, NJ

NJDEP, 1986b. *Summary of Phytoplankton Blooms and Related Events in New Jersey Coastal Waters Summer of 1985.* Division of Water Resources, Bureau of Monitoring and Data Management, NJDEP, Trenton, NJ

NJDEP. 1987a. *New Jersey Stormwater Program.* N. J. Dept. of Environmental Protection, Trenton, NJ

NJDEP, 1987b. *A Summary of EPA Research Findings on Stormwater Management.* N.J. Dept. of Environmental Protection, Trenton, NJ

NJDEP, 1987c. *The Cooperative Coastal Monitoring Program, 1985 & 1986.* Division of Water Resources, Bureau of Monitoring Management, NJDEP, Trenton, NJ

NJDEP, 1987d. *Navesink River Pollution Control Implementation Plan*, NJDEP, Trenton, NJ

NJDEP, 1988a. *New Jersey's Coastal Ocean*, The Planning Group, Office of the Commissioner, NJDEP, Trenton, NJ

NJDEP, 1988b. *The Cooperative Coastal Monitoring Program, 1987.* Division of Water Resources, New Jersey Dept. of Env. Prot., Trenton, NJ

NJDEP, 1988c. *Biochemical Monitoring of New Jersey's Nearshore Ocean Waters: June 1977 to June 1988.* NJ Tech. Rpt. No. 42M, Div. of Fish, Game and Shellfish, Bureau of Fisheries, Nacote Creek Research Station, NJDEP, Trenton, NJ

NJDEP, 1988d. *The State of the Ocean* - A Report by the Blue Ribbon Panel on Ocean Incidents, NJDEP, Trenton, NJ

NJDOH, 1988. *Progress Report -A Study of the Relationship Between Illnesses and Ocean Beach Water Quality.* Environmental Health Serv., Div. of Occupational and Environmental Health, New Jersey Dept. of Health, Trenton, NJ

NJMSC, 1987. *The Hudson-Raritan: State of the Estuary - Summary.* Water Quality of New Jersey Coastal Waters, Vol 1, Pt. 1. A Report by the Panel on Water Quality of the Hudson-Raritan Estuary Panel, New Jersey Marine Sciences Consortium, Fort Hancock, NJ

NOAA, 1987. *Proceedings of the Emergency Conference on "Brown Tide" and Other Unusual Algal Blooms.* Oct. 23, 1986, Hauppauge, NY. Office of Ocean and Coastal Resource Management, Natl. Oceanographic and Atmospheric Admin. Printed by the Port Authority of New York and New Jersey, New York, NY

Nordstrom, K.F., 1977. *Coastal Geomorphology of New Jersey, Volume I: Management Techniques and Management Strategies.*, Center for Coastal and Environmental Studies, Rutgers University, New Brunswick, NJ

Odum, H.T., B.J. Copeland, and E.A. McMahan. 1974. *Coastal Ecological Systems of the United States I-IV.* The Conservation Foundation, Washinton, DC

Odum, E. P. 1971. Fundamentals of Ecology, 3rd Ed., W.B. Saunders Co., Philadelphia, PA

Olsen, P., R.A. Kantor, J. Kantor, J. Kurtz, K. Berry, D. Charette, 1985. *An Assessment of Algal and Macroinvertebrate Communities in an Artificial Lagoon System in Barnegat Bay, New Jersey.*, Division of Water Res., Bureau of Monitoring and Data Mgmt., New Jersey Dept. of Environmental Protection, Trenton, NJ

Pearce, J. B., 1980. *The Ocean Pulse and Northeast Monitoring Programs: New Approaches to Monitoring the Quality of Fisheries Habitats.* U.S. Dept. of Commerce, National Oceanic and Atmospheric Admin., National Marine Fisheries Service, Northeast Fisheries Center, Highlands, NJ

Rast, W., G. F. Lee, 1983. *Nutrient Loading Estimates for Lakes.* Journal of Environmental Engineering, 109(2), April 1983, Am. Soc. of Civil Eng., Wash., DC

Rhodehamel, E. C., 1971. *A Hydrologic Analysis of the New Jersey Pine Barrens Region.* Division of Water Policy and Supply, U. S. Geo. Surv., West Trenton, NJ

Ryther J.H., and W. M. Dunstan, 1971. *Nitrogen, Phosphorus, and Eutrophication in the Coastal Marine Environment.* Woods Hole Oceanographic Inst., Woods Hole, MA, in Science, Vol. 171, March, 1971.

SAIC, 1986. *An Environmental Inventory of the New Jersey Coast/New York Bight Relevant to Green Tide Occurrence.* Science Applications International Corp., for U.S. Environmental Protection Agency, Region II, New York, NY

SAIC, 1987. *New Jersey Floatables Study: Possible Sources, Transport, and Beach Survey Results.* Science Applications International Corp., for New Jersey Dept. of Environmental Protection, Trenton, NJ

Smith, J., P. J. Witkowski, and T. V. Fusillo. 1988. *Manmade Organic Compounds in the Surface Waters of the United States: A Review of Current Understanding*. U.S. Geological Survey Circular 1007, USGS, Department of the Interior, Denver, CO

Takacs, F., P. Olsen and K. Wagner, 197X. *Summary of 1978 Phytoplankton Bloom Incidences*. Biological/Technical Support Unit, Div. of Water Resources, Bureau of Water Quality Planning and Management, New Jersey Dept. of Environmental Prot., Trenton, NJ

Tiner, R.W., 1985. *Wetlands of New Jersey*. National Wetlands Inventory, U.S. Fish and Wildlife Service, Region 5, Newton Corner, MA

Thorbjarson, K. W., C. A. Nittrouer, D. J. DeMaster and R. B. McKinney, 1985. *Sediment Accumulation in a Back-Barrier Lagoon, Great Sound, New Jersey*. Jour. of Sedimentary Petrology, Vol. 55, No. 6, Nov., 1985, p. 856-863.

USEPA, 1987. *New York Bight Water Quality, Summer of 1985*. Region II, Surveillance and Monitoring Branch, U. S. Env. Prot. Agency, Edison, NJ

USEPA, 1988. *New York Bight Water Quality*, Summer of 1987. USEPA, Reg. II, New York, NY

II. Best Management Practices

Athanas, C., 1986. *Wetland Basins for Stormwater Treatment: Analysis and Guidelines, Final Report.* Univ. of Maryland, Horn Point Laboratories, Cambridge, MD

Cahill, T.H, and M. Adams, 1988. *The Use of Porous Paving for Groundwater Recharge in Stormwater Management Systems.* 1988 Floodplain/Stormwater Management Symposium, Penn State Univ., State College, PA

Davis, W. J., R. H. McCuen and G. E. Kamedulski, 1978. *The Effect of Storm Water Detention on Water Quality.* International Symposium on Urban Storm Water Management, Univ. of Kentucky, Lexington, KY

DEM, 1980. *Design Manual for BMP Facilities.* Department of Environmental Management, Fairfax County, VA

Dillaha, T. A ., 1988. *Design of Filter Strips for Effective Pollutant Removal.* Virginia Polytechnic Institute and State Univ., Blacksburg, VA

DVRPC, 1981. *New Jersey Stormwater Quantity/Quality Management Manual.* Delaware Valley Regional Planning Comm., for Div. of Water Resources, NJDEP, Trenton, NJ

Ferrara, R.A., and P.Witkowski, 1983. *Stormwater Quality Characteristics in Detention Basins*, ASCE. Journal of Environmental Engineering, 109(2). New York, NY

Grizzard, T.J., C.W. Randall, B.L. Weand and K.L. Ellis, 1986. *Effectiveness of Extended Detention Ponds.* Urban Runoff Quality, ASCE, pp. 323-337, New York, NY

Hannon, J.G, 1980. *Underground Disposal of Storm Water Runoff, Design Guidelines Manual.* California Dept. of Transportation, U.S. Dept. of Trans., Washington, DC

Hantzsche, N., and J. B. Franzini, 1980. *Utilization of Infiltration Basins for Urban Stormwater Management.* International Symposium of Urban Storm Runoff, Univ. of Kentucky, Lexington, KY

Harper, H.H., Y.A. Yousef, and M.P. Wanielista. 1983. *Fate of Heavy Metals in Stormwater Management Systems.* Univ. of Central Florida, Gainesville, FL

Harrington, B. and S. Wong, 1983. *The Effects of Alternative Stormwater Management Design Policy on Detention Basins.* Sediment and Stormwater Division, Maryland Dept. of the Environment, , Annapolis, MD

Harrington, B., 1983. *Wet Pond Criteria to Achieve Water Quality Control.* Maryland Water Resources Administration, Annapolis, MD

Hartigan, J.P., 1986. *Regional BMP Master Plans.* Urban Runoff Quality, ASCE, New York, NY. pp.458-69.

Hickock, E.A., M.C. Hannaman, and N.C. Wenck. 1977. *Urban Runoff Treatment Methods. Vol. I. Non-structural Wetland Treatment.* EPA-600/2-77-217. USEPA, Washington, DC

Highfill, R.E. 1983. *Modern Terracing Systems*. Journal of Soil and Water Conservation. 38(4):336-8.

Kao, D. T., B. J. Barfield, and A. E. Lyons, Jr. 1975. *On-Site Sediment Filtration Using Grass Strips*. National Symposium on Urban Hydrology and Sediment Conrol, University of Kentucky, Lexington, Kentucky.

Kercher, W.C, J.C. Landon and R. Massarelli. 1983. *Grassy Swales Prove Cost-Effective for Water Pollution Control*. Public Works, pp. 53-55.

Kropp, R.H. 1982. *Water Quality Enhancement Design Techniques,* Proceedings - Conference on Storm Water Detention Facilities, ASCE.

Lowrance, R., R. Leonard, and J. Sheridan. 1985. *Managing Riparian Ecosystems to Control Nonpoint Pollution*. Journal of Soil and Water Conservation, 40(1), Jan.-Feb. 1985.

Lynch, J.A., E.S. Corbett and K. Mussallem. 1985. *Best Management Practices for Controlling Nonpoint-Source Pollution on Forested Watersheds*. Journal of Soil and Water Conservation, 40(1), Jan.-Feb. 1985.

MDNR, 1984. *Standards and Specifications for Infiltration Practices*. Stormwater Management Administration, Sediment and Stormwater Division, Maryland Department of Natural Resources, Annapolis, Maryland.

MDNR, 1985. *Inspector's Guidelines Manual for Stormwater Management Infiltration Practices*. Water Resources Administration, Sediment and Stormwater Division, Maryland Department of Natural Resources, Annapolis, MD

MDNR, 1986. *Minimum Water Quality Objectives and Planning Guidelines for Infiltration Practices* . Water Resources Administration, Sediment and Stormwater Division, Maryland Department of Natural Resources, Annapolis, MD

MWCOG, 1979 *Controlling Stormwater Runoff in Developing Areas: Selected Best Management Practices*. Prepared for the Water Resources Planning Board, Metropolitan Washington Council of Governments, Wash., DC

NJDEP, 1986. *A Guide to Stormwater Management Practices in New Jersey*. Division of Water Resources, NJDEP, Trenton, NJ

NJDEP/USDA, 1986. *South Branch Rockaway Creek Stormwater Management Study*. Division of Water Resources and Soil Conservation Service, NJDEP, Trenton, NJ

Nichols, D. S., 1983. *Capacity of Natural Watlands to Remove Nutrients form Wastewater Effluent*. Journal of Water Pollution Control Federation, 55(5), pp. 495-505.

NCSU, 1982a. *Best Management Practices for Agricultural Nonpoint Source Control: I. Animal Waste*. North Carolina Agricultural Extension Service, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, NC

NCSU, 1982b. *Best Management Practices for Agricultural Nonpoint Source Control: II. Commercial Fertilizer*. North Carolina Agricultural Extension Service, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, NC

NCSU, 1982c. *Best Management Practices for Agricultural Nonpoint Source Control: III. Sediment*. North Carolina Agricultural Extension Service, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, NC

NVPDC, 1987. *BMP Handbook for the Occoquan Watershed.* North Virginia Planning District Commision, Annandale, VA

Novotny, V., and G. Chester, 1981. *Handbook of Nonpoint Pollution Sources and Management.* Environmental Engineering Series,Van Nostrand Reinhold, Pub., New York, NY

Oakland, P., 1983. *An Evaluation of Urban Storm Water Pollutant Removal through Grassed Swale Treatment.* 1983 International Symposium on Urban Hydrology, Hydraulics and Sediment Control, University of Kentucky, Lexington, KY

Pensyl, K., and P. Clement, 1987. *Results of the State of Maryland Infiltration Practices Survey.* Sediment and Stormwater Division, Maryland Department of the Environment, Annapolis, MD

Pensyl, K., 1986. *Performance of Infiltration Trenchs and Other Infiltration Practices.* Sediment and Stormwater Administration, Maryland Department of the Environment, Annapolis, MD

Pilkey, Orrin Jr., D. C. Sharma, H. R. Wanless, L. J. Doyle, O. H. Pilkey, Sr., W. J. Neal, and B. L. Gruver, 1984. *Living with the East Florida Shore.* Duke University Press, Durham, NC

Pimentel, D.V, and G.E. Oswald, 1986. *High Tech Approach to Urban Stormwater Management.* Watershed Management Division, Public Works Department, Austin, TX

PBSJ, 1982. *Evaluation of Two Best Management Practices: A Grassy Swale and a Retention/Detention Pond.* Post, Buckley, Schuh, and Jernigan, Inc., for the Brevard County Water Resources Department and County Board of Commisioner, Brevard County, FL

Randall, C.W. 1982. *Stormwater Detention Ponds for Water Quality Control.* Proceedings - Conference on Storm Water Detention Facilities (ASCE) .New York, NY.

Schueler,T. S. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs.* Department of Environmental Programs, Metropolitan Washington Council of Governments, Wash., DC

Schueler, T., R. Magill, M. P. Sullivan and C. Wiegand, 1985. *Comparative Pollutant Removal Capability, Economics and Physical Suitability of Urban Best Management Practices in the Washington D.C. Metropolitan Area.* Department of Environmental Programs, Metropolitan Washington Council of Governments, Washington, DC

Schueler, T., and M. P. Sullivan, 1983. *Management of Stormwater and Water Quality in an Urbanizing Watershed.* 1983 International Symposium on Urban Hydrology, Hydraulics, and Sediment Control, University of Kentucky, Lexington, KY

Shaver, H.E. 1986. *Infiltration as a Stormwater Management Component.* Urban Runoff Quality: Impact and Quality Enhancement Technology, ASCE, pp. 366-81, New York, NY.

Sullivan, R.J. 1981. *Urban Stormwater Management, Special Report No. 49.* American Public Works Association, Chicago, IL

Swift, L.W., Jr., 1984. *Gravel and Grass Surfacing Reduces Soil Loss from Mountain Roads.* Forest Science, 30(3):657-70.

Thelen, E., and L. F. Howe, 1978. *Porous Pavement: Principles of Development and a Porous Pavement Design Manual.* Lib. Cong. Cd. No. 78-4314, The Franklin Institute Press, Philadelphia, PA

Tollner,.E.W., B. J. Barfield, and J. C. Hayes, 1982. *Sedimentology of Erect Vegetal Filters.* Proceedings of Hydraulics Division, ASCE, 108(12): 1518-1531.

EPA, 1987. *Guide to Nonpoint Source Pollution Control.* Office of Water, U. S. Environmental Protection Agency, Washinton, DC

EPA, 1986. *Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality.* Nonpoint Source Branch, Office of Water, U. S. Environmental Protection Agency, Washinton, DC

VSWCB, 1986. *Best Management Practices Handbook.* Planning Bulletin 321, Virginia State Water Control Board, Richmond, VA

Whipple, W., Jr. 1979. *Dual-Purpose Detentin Basins.* Journal of the Water Resources Planning and Management Division. ASCE, Proc. Paper 14860, September 1979, W.R. 2, P.404.

Whipple, W., S.D. Faust, W. Renwick, N. K. Wiegand. 1983. *Flood Control Effectiveness of Systems of Dual Purpose Detention Basins.* Center for Coastal and Environmental Studies, Rutgers University, New Brunswick, NJ

Wigington, P.J., C.W. Randall, and T.J. Grizzard, 1983. *Accumulation fo Selected Trace Metals in Soils of Urban Runoff Detention Basins.* Water Resources Bulletin, 19(5), 709-718.

Wong, S.L., R.J. McCuen, 1982. *The Design of Vegetative Buffer Strips for Runoff and Sediment Control.* Tidewater Administration, Department of Natural Resources, Annapolis, MD

Young, R, T. Huntrods, and W. Anderson, 1980. *Effectiveness of Vegetated Buffer Strips in Controlling Pollution fro Feedlot Runoff.* Journal of Environmental Quality. 9(3):483-7.

III. General Non Point Source

APWA, 1969. Water Pollution Aspects of Urban Runoff, Am. Public Works Assn., for the FWPCA. WP-20-15. USGPO, Wash., DC

Athayde, D.N., and P. Tobin. 1986. *EPA's Perspective on Urban Nonpoint Sources.* Urban Runoff Quality: Impacts and Water Quality Enhancement Technologies. ASCE, New York, NY.

ASIWPCA, 1983. *America's Clean Water: The States' Evaluation of Progress 1972-1982.* Assn. of State and Interstate Water Poll. Control Admin., Washington, DC

ASIWPCA, 1984. *Proceedings of the National Retreat on Goals, Expectations, and Future Directions of State Nonpoint Source Management Programs.* Assn. of State and Interstate Water Poll. Control Admin., Washington, DC

ASIWPCA, 1985. *America's Clean Water: The States' Nonpoint Source Management Assessment 1985.* Assn. of State and Interstate Water Poll. Control Admin., Washington, DC

Baker, D.B, and J.W. Kramer, 1973. *Phosphorus Sources and Transport in an Agricultural Basin of Lake Erie.* Proceedings of 16th Conference of Great Lakes Res., Ann Arbor, MI

Baker, D., 1984. *Fluvial Transport and Phosphorus Processing of Sediments and Nutrients in Large Agricultural River Basins,.* EPA-600/8-83-054. U. S. Env. Prot. Agency, Athens, GA

Baker, D., 1985. *Regional Water Quality Impacts of Intensive Row-crop Agriculture: The Lake Erie Basin Case Study.* Jour. Soil & Water Consv., Vol. 40, No. 1, Jan., 1985. SCSA, Ankeny, IA

Browne Associates, Inc, 1983. *Lake Nockamixon Phase 1 Diagnostic - Feasibility Study.,* F. X. Browne Assoc. for the Bucks Co. Cons. Dist., Doylestown, PA

Cahill, T.H., P. Imperato, and F.H. Verhoff, 1974. *An Evaluation of Phosphorus Dynamics in a Watershed.* Journal of the Env. Engineering Div., ASCE. 100:EE2, Proceedings Paper 104455.

Cahill, T. H., J. Adams and D. Baker, 1976. *The Importance of Diffuse Source Pollutants In River Chemistry,* Proc. 19th Conf. on Great Lakes Res., May 4, 1976, Univ. of Guelph, Ont. Min. of the Env., Ontario, Canada

Cahill, T. H., 1977. *Form and Sediment Associations of Nutrients - Phosphorus.* Proc. on The Fluvial Transport of Sediment-Associated Nutrients and Contaminants, Pollution from Land Use Reference Group, International Joint Comm., Windsor, Ontario

Cahill, T.H, R.W. Pierson, Jr., and B.R. Cohen. 1979. *Nonpoint Source Model Calibration in Honey Creek Watershed.* EPA-600/3-79-054, U. S. Env. Prot. Agency, Athens, GA

Cahill, T. H., 1985. *Phosphorus Criteria In Lake and Estuary Drainage Systems*. Nesh. Water Res. Auth., Doylestown, PA

Chittenden, W. 1987. *Restoring the Anacostia River: A Regional Challenge*. The Region: Metropolitan Washington Council of Governments, 28(1), Wash., DC

Clark, J., 1977. *Coastal Ecosystems: Ecological Considerations for Management of the Coastal Zone*. The Conservation Foundation, Washington, D.C.

COE, 1975. *Lake Erie Wastewater Management Study: Preliminary Feasibility Report*. Buffalo Dist., U.S.Army Corps of Eng., Buffalo, NY

Duda, A. M., 1982. *Municipal Point Source and Agricultural Nonpoint Source Contributions to Coastal Eutrophication*. Water Resources Bulletin, 18(3):397-407.

Ferrara, R.A., and K. Salvage. 1982. *Stormwater Pollutant Settleability*. Department of Civil Eng., Princeton Univ., Princeton, NJ

Field, R. 1980. *EPA Research in Urban Stormwater Pollution Control*. Journal of the Hydraulics Division, ASCE, 106(HY5):819-35.

Gianessi, L.P., 1981. *The Resources for the Future National Data Base for Nonpoint Source Policy Assessment*. Resources for the Future, Washington, DC

Haith, D.A., and L.J. Tubbs. 1981. *Watershed Loading functions for Nonpoint Sources*. Journal of Environmental Engineering, 107(EE1):121-37.

Hammer, T. R., 1972. *Stream Channel Enlargement Due to Urbanization*. Water Resources Research, Dec., 1972.

Hammer, T. R., 1977. *Interim Report: Urban Land/Water Relationships*. EPA 68-01-3551, USEPA, Wash., DC

ICPRB, 1984. *Non-Point Pollution in the Potomac River Basin*. Interstate Commission on the Potomac River Basin, Bethesda, MD

ICPRB, 1985 . *The Potomac: Putting the Pieces Together*. Interstate Commission on the Potomac River Basin, Bethesda, MD

Johnson, M., and N. Berg. 1979. *A Framework for Nonpoint Pollution Control in the Great Lakes Basin*. Journal of Soil and Water Con., 34(2). JWSC, Ackeny, IA

Johnston, D., 1988. *Scientists Seek Better Tests for Health Threats in Ocean*. Philadelphia Inquirer, Aug. 17, 1988, Philadelphia, PA

JSWC, 1985. *Nonpoint Water Pollution - A Special Issue*. Journal of Soil and Water Conservation, Vol. 40, No. 1, JSWC, Ackeny, IA

LEWMS, 1977. *The Lake Erie Wastewater Management Study, Summary Report*. Buffalo Dist., U. S. Army Corps of Eng., Buffalo, NY

Leopold, L. B., M. G. Wolman and J. P. Miller, 1976. Fluvial Processes In Geomorphology. Freeman & Co., Publ., San Francisco, CA.

Mackenthun, K. M., 1965. Nitrogen and Phosphorus In Water. Taft Eng. Ctr., USDHEW, PHS, Cinn., OH. USGPO, Wash., DC

McElroy, A.D., S.Y. Chiu, J.W. Nebgen, A. Aleti and F.W. Bennet, 1976. *Loading Functions for Assessment of Water Pollution from Nonpoint Sources*. USEPA, Washington, DC

Monteith, T.J., R.A.C. Sullivan, T.M. Heidtke, and W.C. Sonsogni. 1981. *Water Shed Handbook: A Management Technique for Choosing Among Point and Nonpoint Control Strategies*. USEPA, Chicago, IL

NCSU, 1984. *Conceptual Framework for Assessing Agricultural Nonpoint Source Projects*. North Carolina State Univ., for North Carolina Agricultural Extension Service. Raleigh, NC

Ogg, C., and H. B. Pionke, 1986. *Water Quality and the New Farm Policy Initiatives*. Journal of Soil and Water Cons., March-April 1986. JSWC, Ackeny, IA

OWML, 1983. *Final Contract Report: Washington Area NURP Project*. Occoquan Watershed Monitoring Lab., Manassas, VA for Metropolitan Washington Council of Govt.. Wash., DC

Park, R.A., C.D. Collins, D.K. Leung, C.W. Boylen, J. Albanses, P. deCaprariis, and H. Forstner. 1978. *The Aquatic Ecosystem Model MS. CLEANER*. Center for Ecologic Modeling, Rensselaer Polytechnic Institute, Troy, NY.

PADER, 1984a. *Agricultural Nonpoint Source Abatement Program for the Chesapeake Bay*. Bureau of Soil and Water Conservation, PA Dept. of Env. Res., Harrisburg, PA

PADER, 1984b. *An Evaluation of Pennsylvania's Erosion and Sedimentation Control Program*. Bureau of Soil and Water Cons., PA Dept. of Env. Res., Harrisburg, PA

PADER,1984c. *Commonwealth of Pennsylvania -1984 Water Quality Inventory*. Bureau of Water Quality Management, PA Dept. of Env. Res., Harrisburg, PA

Podar, M.K., J.C. Crossman, D.E. Burmaster, R.J. Ruane, J.A. Jaksch, G.Hauser, and S.L. Sessions, 1985. *Optimizing Point/Nonpoint Source Tradeoff in the Holston River Near Kingsport, Tennessee*. Univ. of Tenn., Knoxville, TE

Sawicki, D., L. B. Judd, G. Eggleston, C. Bluemke, and D. Dupies, 1984. *Nonpoint Source Water Pollution Control in the United States: Survey of State and Areawide Water Quality Planning Agencies*. Water Resources Center, Univ. of Wisc., Madison, WI

Schueller, J.P., 1984. *An Assessment of Agricultural Nonpoint Source Pollution in Selected High Priority Watersheds in Pennsylvania*. Bureau of Soil and Water Cons., PA Dept. of Env. Res., Harrisburg, PA

Shahane, A. N. 1982. *Estimation of Pre- and Post-Development Nonpoint Water Quality Loadings*. Water Resources Bulletin, American Water Resources Association, 18(2): 231-237, April 1982.

Smith, J.A., P.J. Witkowski, and T.V. Fusillo, 1988. *Manmade Organic Compounds in the Surface Waters of the United States - A Review of Current Understanding*. U.S.G.S. Cir. 1007, Federal Center, Denver, CO

Stenstrom, M.K., G.S. Herman and T.A. Burstynsky, 1984. *Oil and Grease in Urban Stormwater*. Journal of Environmental Engineering, 110(1):58-72.

Susquehanna River Basin Commission. 1984. *Assessment of Nutrient Sources from Main Stem and Selected Watersheds in the Susquehanna River Basin.*

Ulanoski, J., R. H. Shertzer, J. L. Barker, R. T. Hartman, 1981. *Trophic Classification and Characteristics of Twenty-Six Publicly Owned Pennsylvania Lakes.* Bureau of Water Quality Management, PA Dept. of Env. Res., Harrisburg, PA

USDA, 1980. *Rural Clean Water Program.* Agricultural Stabilization and Conservation Service, USDA, Wash., DC

USDA, 1983. *Water Quality Field Guide.* Soil Conservation Ser., U. S. Dept. of Ag., Wash., DC

USDA/USEPA, 1984. *Proceedings of the Rural Clean Water Program*, April 2-5, 1984. USDA/USEPA National Water Quality Evaluation Project, Dept. of Biological and Agricultural Eng., North Carolina State Univ., Raleigh, NC

USEPA, 1975. *Non-Point Source Pollution Seminar.* Section 108(a) Program, Office of the Great Lakes Coordinator. USEPA, Reg. V, Chicago, IL

USEPA, 1979. *Institutional Bases for Control of Nonpoint Source Pollution.* Office of Water and Waste Management, U. S. Env. Prot. Agency, Washington, DC

USEPA. 1983. *Results of Nationwide Urban Runoff Program. Volume I. Final Report.* Water Planning Division, U. S. Env. Prot. Agency, Wash., DC

USEPA, 1984a. *Water Research Annual Report, 1984.* Office of Research and Development, U. S. Env.Prot. Agency, Wash., DC

USEPA, 1984b. *FY-1985 EPA Research Program Guide.* Office of Research and Development, U. S. Env. Prot. Agency, Washington, DC

USEPA, 1984c. *Lake Erie Demonstration Projects: Evaluating Impacts of Conservation Tillage on Yield, Cost, and Environment.* Great Lakes National Program Office. USEPA, Reg. V, Chicago, IL

USEPA, 1984d. *Research Outlook 1984.* Office of Research and Development, U. S. Env. Prot. Agency, Washington, DC

USEPA, 1985a. *Guidelines for Evaluation of Agricultural Nonpoint Source Water Quality Projects.* U. S. Env. Prot. Agency, Wash., DC

USEPA, 1985b. *Perspectives on Nonpoint Source Pollution: Proceedings of a National Conference.* Office of Water, Regulations and Standards, May 1985, Washington, DC

USEPA, 1985c. *Report to Congress: Nonpoint Source Pollution in the U.S.* Office of Water Operations, Water Planning Division, Washington, DC

USEPA, 1986. *Tackling Nonpoint Water Pollution.* Office of Public Affairs, EPA Journal 12(4), May 1986, Washington, DC

Whipple, W, J.V. Hunter. 1981. *Settleability of Urban Runoff Pollution.* Water Resources Research Institute, Rutgers University, Pisc., NJ